HANDBOOK OF Respiration

National Academy of Sciences
National Research Council

W. B. Saunders Company

HANDBOOK
of
RESPIRATION

Analysis and Compilation by

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Prepared under the direction of the Committee
on the Handbook of Biological Data

DIVISION OF BIOLOGY AND AGRICULTURE
THE NATIONAL ACADEMY OF SCIENCES
THE NATIONAL RESEARCH COUNCIL

W. B. SAUNDERS COMPANY
Philadelphia and London

Made in the United States of America

LIBRARY OF CONGRESS CATALOG CARD NUMBER: 58-13138

Foreword

The Handbook of Respiration is the sixth in a series of publications*, each containing information, chiefly tabular, in one or more fields of the biological sciences. These handbooks have been prepared under the general direction of the Committee on the Handbook of Biological Data, Division of Biology and Agriculture, National Academy of Sciences--National Research Council.

The information for the present Handbook was prepared and contributed by leading authorities in the field of respiration. The data were assembled, tabulated, and edited by the Handbook staff, then critically reviewed and authenticated by experts in the areas covered in this volume.

On behalf of the Committee, acknowledgment is made to the numerous scientists who have been so liberal with their time and advice; to Wright Air Development Center United States Air Force, the National Institutes of Health of the Public Health Service, the Division of Biology and Medicine of the Atomic Energy Commission, the Office of Naval Research, the Office of the Surgeon General of the Army, and the Army Chemical Center, for generous support and cooperation, which have made possible the production of this book. The Air Force participation in this undertaking was carried out under Contract No. AF 33(616)-3972 with the National Academy of Sciences. Dr. J. W. Heim, Aero Medical Laboratory, Wright Air Development Center, served as contract monitor.

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Handbook of Biological Data	1956
Handbook of Toxicology, Vol. II, Antibiotics	1957
Handbook of Respiration	1958

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Introduction

This Handbook has been prepared for the purpose of making readily available in a single, comprehensive compilation useful data on respiration and associated phenomena. To this end, information has been organized for ready reference in the form of tables, graphs, nomograms, schematic diagrams, and line charts. Contents of the volume have been made available and authenticated by some 400 leading investigators in the fields of biology and medicine. The extended review process to which all tables have been subjected was designed to eliminate, insofar as possible, both errors and such strongly controversial or questionable material as tends naturally to inhere in a work of this scope and complexity.

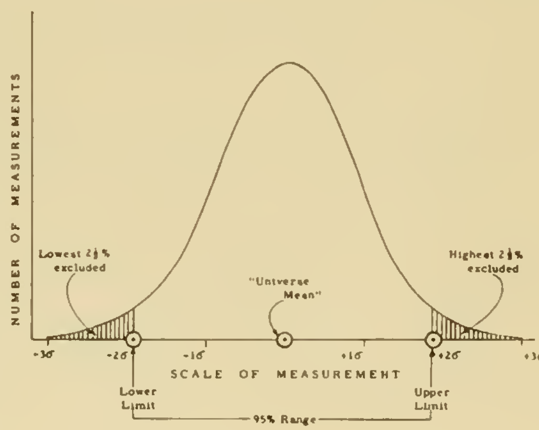
Frequently, a group of tables is preceded by an explanatory headnote designed to serve as an introduction to the subject matter, or to account for inconsistencies and inclusion of controversial material. Usually, individual tables are supplied with a short headnote containing such essential information as definitions; units, methods, and conditions of measurement; conversion factors; abbreviations; and estimate of the range of variation. Following each presentation there appears a list of contributors of the material, together with bibliographic references. In the latter, abbreviations conform wherever possible to the LIST OF ABBREVIATIONS FOR SERIAL PUBLICATIONS, Fourth Series, Army Medical Library, Washington, D. C. (U. S. Government Printing Office, 1948), and the 1955 SUPPLEMENT thereto.

Technical and mechanical problems in the preparation of copy made impossible the use of standard symbols and abbreviations in respiratory physiology as recommended in FEDERATION PROCEEDINGS 9:602, 1950; the same limitations precluded the use of italics. The symbols d and l indicate, in terms of optical rotation, respectively dextro- and levorotatory; D and L are used for dextro and levo in the configurational sense for amino acids and carbohydrates or for the stereoisomeric forms of an organic substance.

The number of subjects and observations has been given whenever such information was available, provided only that space permitted. There may on occasion appear between two tables differences in values for the same specifications, and there may be found certain inconsistencies in nomenclature and occasional overlapping of coverage. These represent not oversights, nor failure to choose between alternatives; on the contrary, they result from the deliberate intention of the research staff to respect the judgment and preferences of individual contributors. On the other hand, with only the rarest of exception, each presentation is itself internally consistent.

Values are generally presented as a mean and the upper and lower limit of the 95% range. Letter designations (a, b, c, d) identify types of ranges:

(a) By the method of greatest accuracy, the 95% range is obtained by fitting a recognized type of frequency curve to a group of measured values and excluding the extreme 2.5% of area under the curve at each end (see sketch). Estimate is made by this procedure only when the group of values is relatively large.



(b) By a less accurate method, the 95% range is estimated by a simple statistical calculation, assuming a normal distribution and using the standard deviation. This estimate is used when the group of values is too small for curve fitting, as is usually the case.

(c) A third and still less accurate procedure for estimate of the 95% range is simply to take as range limits the highest value and lowest value of the reported sample group of measurements. It underestimates the 95% range for small samples (3 or 4 values) and overestimates for larger sample sizes, but may be used in preference to the preceding method when the sample shows convincing evidence that the variable is asymmetrical in distribution.

(d) The upper and lower limits of the range of variation, as commonly encountered by an investigator experienced in measuring the quantity in question, constitute still another estimate of the 95% range. The trustworthiness of limits so placed should not be underestimated.

Although the data in each table are the best available at the time the table was prepared, it is recognized that all data are subject to revision as investigators improve techniques and make more measurements. The reader is invited to submit any values or ranges that he feels should be given consideration, and is particularly invited to add to the coverage of animal forms.

HANDBOOK of RESPIRATION

1. ABSOLUTE LUNG VOLUMES, DEFINITIONS AND CONVERSIONS: ATPS, BTPS, AND STPD CONDITIONS

Gas volume in the lung exists at Body Temperature and atmospheric Pressure and is completely Saturated with water vapor at body temperature--hence the designation BTPS.

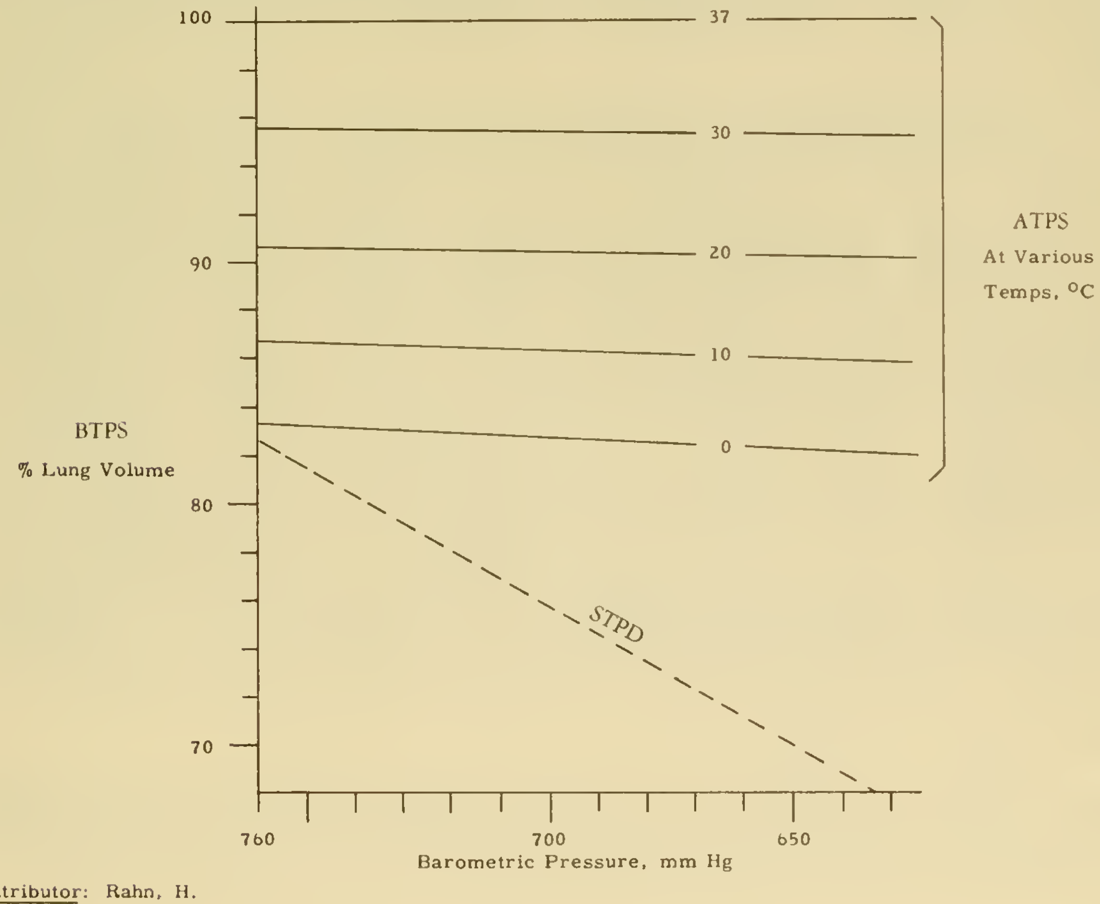
However, once the gas has been blown into a measuring device such as a spirometer, the temperature will have dropped to the spirometer or Ambient Temperature; although the gas volume is still Saturated with water vapor at the lower ambient temperature the water vapor volume is reduced. The Pressure of the atmosphere is the same. This condition is designated ATPS.

Under average laboratory conditions (ATPS), the "true" lung volume (BTPS) will shrink, in response to the ambient temperature and barometric pressure, to perhaps 93%, as shown in the figure below. If this lung volume is then converted to conditions of Standard Temperature and Pressure with all water vapor removed (or Dry), this STPD value will be approximately 83% of the BTPS lung volume--sometimes even less in accordance with the barometric pressure (also as shown in the figure below).

It must also be borne in mind that lung volume measurements are often made on closed breathing circuits which contain a CO_2 absorber. Any volume expired into such a system will, of course, be automatically reduced by the percentage of CO_2 in the expired air; for a Vital Capacity obtained after full inspiration and before maximal expiration, this reduction may well be of the order of 2-3%. This discrepancy must be considered in making reference to "absolute volumes."

All lung volumes are normally recorded at ATPS conditions. Conversion to BTPS conditions which represent true or anatomical lung volume requires knowledge of room or spirometer temperature and approximate barometric pressure.

True lung volume (BTPS) = lung volume at ATPS $\times \frac{310}{273+t} \times \frac{P_B - pH_2O}{P_B - 47}$, where t = spirometer temperature in degrees C; P_B = barometric pressure in mm Hg; and pH_2O = vapor pressure of water at spirometer temperature t. 310 is absolute body temperature of 37°C, and 47 mm Hg is the vapor pressure of water at 37°C.



Contributor: Rahn, H.

2. FACTORS FOR CONVERSION OF GAS VOLUMES FROM ATPS TO BTPS CONDITIONS

ATPS = At Ambient Temperature and atmospheric Pressure, completely Saturated with water vapor. BTPS = At Body Temperature (37°C) and atmospheric Pressure, completely Saturated with water vapor. Atmospheric pressure is assumed to be standard (760 mm Hg). It is unnecessary to correct for small deviations from standard barometric pressure. For additional information on these concepts see Page 1.

	Factor to Convert Volume to 37°C Saturated	When Gas Temperature (°C) is	With Water Vapor Pressure (mm Hg) of
	(A)	(B)	(C)
1	1.102	20	17.5
2	1.096	21	18.7
3	1.091	22	19.8
4	1.085	23	21.1
5	1.080	24	22.4
6	1.075	25	23.8
7	1.068	26	25.2
8	1.063	27	26.7
9	1.057	28	28.3
10	1.051	29	30.0
11	1.045	30	31.8
12	1.039	31	33.7
13	1.032	32	35.7
14	1.026	33	37.7
15	1.020	34	39.9
16	1.014	35	42.2
17	1.007	36	44.6
18	1.000	37	47.0

Reference: Comroe, J. H., Jr., "Methods in Medical Research," vol 2, pp 74-244, Chicago: The Year Book Publishers, Inc., 1950.

3. TEMPERATURE AT VARIOUS ALTITUDES

U. S. standard atmosphere.

	Altitude		Temperature		
	ft	km	°C	°F	°K
	(A)	(B)	(C)	(D)	(E)
1	0	0	15.0	59	288.0
2	5,000	1.524	5.1	41.2	278.1
3	10,000	3.049	-4.8	23.3	268.2
4	15,000	4.573	-14.7	5.5	258.3
5	20,000	6.098	-24.6	-12.3	248.4
6	25,000	7.622	-34.5	-30.2	238.5
7	30,000	9.147	-44.4	-48.0	228.6
8	35,000	10.671	-54.3	-65.8	218.7
9	40,000	12.196	-55.0	-67.0	218.0
10	50,000	15.245	-55.0	-67.0	218.0
11	60,000	18.294	-55.0	-67.0	218.0
12	70,000	21.483	-55.0	-67.0	218.0
13	80,000	24.392	-55.0	-67.0	218.0
14	90,000	27.441	-55.0	-67.0	218.0
15	100,000	30.490	-55.0	-67.0	218.0
16	200,000	60.980	33.8	93.0	306.8
17	300,000	91.470	-2.2	28.0	270.0

Contributor: Haber, F.

References: [1] Willis, R. G., National Advisory Committee For Aeronautics, Tech. Rept. No. 147, 1922. [2] Diehl, W. S., National Advisory Committee For Aeronautics, Tech. Rept. No. 218, 1925. [3] Bromdracher, W. G., National Advisory Committee For Aeronautics, Tech. Rept. No. 538, 1935. [4] Warfield, C. N., National Advisory Committee For Aeronautics, Tech. Rept. No. 1235, Tech. Note 1200, 1947.

4. ALTITUDE VS ATMOSPHERIC PRESSURE, O_2 PARTIAL PRESSURE, AND AIR DENSITY

	Altitude		Pressure						pO_2	Density	Weight	Density[4]
	ft	km	atm[1]	mm Hg	in. Hg	psi[2]	millibar	Ratio[3]	mm Hg	g/cu cm	lb/cu ft	Ratio
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
1	0	0	1.000	760.0	29.92	14.70	1013.2	1.00	159.2	1.25×10^{-3}	0.07651	1.00
2	5,000	1.524	0.832	632.3	24.89	12.23	842.9	8.32×10^{-1}	132.5	1.08×10^{-3}		8.62×10^{-1}
3	10,000	3.049	0.688	522.9	20.59	10.11	697.1	6.88×10^{-1}	109.5	9.22×10^{-4}	0.05649	7.38×10^{-1}
4	15,000	4.573	0.564	428.6	16.87	8.288	571.4	5.64×10^{-1}	89.8	7.86×10^{-4}		6.29×10^{-1}
5	20,000	6.098	0.459	348.8	13.73	6.745	465.0	4.59×10^{-1}	73.1	6.66×10^{-4}	0.04075	5.33×10^{-1}
6	25,000	7.622	0.371	282.0	11.10	5.452	375.9	3.71×10^{-1}	59.1	5.60×10^{-4}		4.48×10^{-1}
7	30,000	9.147	0.297	225.7	8.885	4.364	300.9	2.97×10^{-1}	47.3	4.67×10^{-4}	0.02861	3.74×10^{-1}
8	35,000	10.671	0.235	178.6	7.031	3.453	238.1	2.35×10^{-1}	37.4	3.87×10^{-4}		3.10×10^{-1}
9	40,000	12.196	0.185	140.6	5.535	2.719	187.4	1.85×10^{-1}	29.4	3.06×10^{-4}	0.01872	2.45×10^{-1}
10	50,000	15.245	0.115	87.4	3.44	1.69	116.5	1.15×10^{-1}	18.3	1.90×10^{-4}	0.01161	1.52×10^{-1}
11	60,000	18.294	0.071	54.1	2.13	1.05	72.1	7.12×10^{-2}	11.3	1.18×10^{-4}	0.00720	9.41×10^{-2}
12	70,000	21.483	0.044	33.6	1.32	0.65	44.8	4.42×10^{-2}	7.0	7.30×10^{-5}	0.00447	5.84×10^{-2}
13	80,000	24.392	0.027	20.8	0.82	0.40	27.8	2.74×10^{-2}	4.3	4.52×10^{-5}	0.00277	3.62×10^{-2}
14	90,000	27.441	0.017	12.9	0.51	0.25	17.2	1.70×10^{-2}	2.7	2.80×10^{-5}	0.00172	2.24×10^{-2}
15	100,000	30.490	0.011	8.0	0.32	0.16	10.6	1.05×10^{-2}	1.7	1.74×10^{-5}	0.00107	1.39×10^{-2}
16	200,000	60.980	3.15×10^{-4}	0.24	0.009	0.005	0.32	3.14×10^{-4}	0.05	3.28×10^{-7}		2.63×10^{-4}
17	300,000	91.470	7.23×10^{-6}	0.0055	0.0002	0.0001	0.0073	7.23×10^{-6}	0.00011	8.57×10^{-9}		6.86×10^{-6}

/1/ Atmospheres. /2/ Absolute pressure, lb/sq in. /3/ Pressure at given altitude vs pressure at sea level. /4/ Density at given altitude vs density at sea level.

Contributors: (a) Haber, F., (b) ZoBell, C. E.

References: [1] Willis, R. G., National Advisory Committee for Aeronautics, Tech. Rept. No. 147, 1922. [2] Diehl, W. S., National Advisory Committee for Aeronautics, Tech. Rept. No. 218, 1925. [3] Bromdracher, W. G., National Advisory Committee for Aeronautics, Tech. Rept. No. 538, 1935. [4] Warfield, C. N., National Advisory Committee for Aeronautics, Tech. Rept. No. 1235, Tech. Note 1200, 1947.

5. CHARACTERISTICS OF RESPIRATORY MEDIA

The solvents, water or nitrogen, through which exchange of O_2 and CO_2 occur, are the primary substances mechanically inspired by animals that actively ventilate the respiratory organ. Values in parentheses are relative coefficients with O_2 as unity.

	Variable	Media			
		Aquatic (H_2O)		Atmospheric (N_2)	
		Ocean	Fresh	Sea Level	6000 m
	(A)	(B)	(C)	(D)	(E)
1	Temperature, °C	-2.0 to 30.0	2.0-32.0	0.7-15.7	-28.1 to -15.1
2	Pressure, total, mm Hg	760-760,000	760-20,000	760	347.5-360.2
3	Density, g/L	1027[1], 20°C	1000[1], 4°C	1.223-1.290	0.649-0.659
	Concentration				
4	H_2O, vol %	100.00	100.00	1.00[2]	1.00[2]
5	N_2, vol %	1.03[1], 15°C	1.33[1], 15°C	78.03 (STP)	78.03 (STP)
6	CO_2, vol %	0.02[1], 15°C	0.03[1], 15°C	0.03 (STP)	0.03 (STP)
7	O_2, vol %	0.58[1], 15°C	0.72[1], 15°C	20.99 (STP)	20.99 (STP)
8	Salts, °/oo	34.48[1]	0.18[1]		
9	pH	7.5-8.4	3.2-10.6		
10	Inert gases, vol %	Traces	Traces	0.95 (STP)	0.95 (STP)
	Partial Pressure (Tension)				
11	H_2O, mm Hg	12.79, 15°C	6.10, 4°C	6.40[3], 15°C	0.72[3], -15°C
12	N_2, mm Hg	593.02 (STP)	593.02 (STP)	593.02 (STP)	281.06[4] (STP)
13	CO_2, mm Hg	0.23[1] (STP)	0.23[1] (STP)	0.23 (STP)	0.11[4] (STP)
14	O_2, mm Hg	159.52[1] (STP)	159.52[1] (STP)	159.52 (STP)	75.61[4] (STP)
15	Inert gases, mm Hg	7.46 (STP)	7.46 (STP)	7.46 (STP)	3.42[4] (STP)
16	Total pressure, mm Hg	760.00 (STP)	760.00 (STP)	760.00 (STP)	360.20 (STP)
	Diffusion Coefficient (ml/min/sq cm x cm at 760 mm Hg, 20°C)				
17	N_2		0.000018[5] (0.53)		
18	CO_2		0.000785[5] (23.1)		
19	O_2		0.000034 (1)	11.0	

/1/ Averages of many determinations; vary widely with conditions of measurement. /2/ Varies, but never absent and always of biological significance. /3/ Calculated for 50% relative humidity. /4/ Calculated. /5/ Calculated from measured value for O_2 (20°C) and relative coefficients (18° - 19°C).

Contributor: McCutcheon, F. H.

References: [1] Heilbrunn, L. V., "General Physiology," Philadelphia: W. B. Saunders Co., 1952. [2] Hodgman, C. D., "Handbook of Chemistry and Physics," Cleveland: Chemical Rubber Publishing Co., 1948. [3] Krogh, A., J. Physiol., Lond. 52:391, 1919. [4] Pearse, A. S., "Animal Ecology," New York: McGraw-Hill, 1939. [5] Sverdrup, H. U., Johnson, M. W., and Fleming, R. H., "The Oceans," New York: Prentiss-Hall, 1946.

6. CHARACTERISTICS OF RESPIRATORY MOLECULES

Values, unless otherwise indicated, are for standard conditions (STP) of temperature (0°C) and pressure (760 mm Hg).

	Type	Weight (O = 16)	Diameter[1] cm x 10^{-8}	Density g/L	Mean Free Path cm x 10^{-6} (750 mm Hg)	Collision Frequency (20°C)	Average Velocity cm x 100/sec	Water Solubility vol %		
								STP	20°C	40°C
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	N_2	28.02	3.15-3.53	1.251	8.50	5070	454	2.35	1.54	1.18
2	H_2O	18.02	3.0-5.0	0.005-0.030[2]			566			
3	CO_2	44.01	3.34-3.40	1.977	5.56	6120	362	171.3	87.8	53.0
4	O_2	32.00	2.92-2.98	1.429	9.05	4430	425	4.89	3.10	2.31

/1/ Range indicates variations with method of measurement (e.g., viscosity, heat conductivity). /2/ Water vapor in saturated air, i.e., in equilibrium with water, at 0°C and 30°C.

Contributor: McCutcheon, F. H.

References: [1] Dorsey, N. E., "Properties of Ordinary Water Substances in All Its Phases," New York: Reinhold, 1940. [2] Hodgman, C. D., "Handbook of Chemistry and Physics," Cleveland: Chemical Rubber Publishing Co., 1948.

7. COMPOSITION AND PARTIAL PRESSURE OF RESPIRATORY GASES: MAN

Values in parentheses conform to estimate "d" of the 95% range (cf Introduction).

	Gas	Water		Nitrogen		Oxygen		Carbon Dioxide		Reference
		vol %	mm Hg	vol %	mm Hg	vol %	mm Hg	vol %	mm Hg	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Ventilated Gas									
1	Inspired	0[1]	±5.7[2]	79.02[1]	596[2]	20.95[1]	158[2]	0.03[1]	0.30[2]	B, D, F, H, 1;C, E, G, 1, 2
2	Alveolar[3]	0[1]	47[4]	80.40[1]	573[4]	14.00[1]	100[4]	5.60[1]	40[4]	2
3	Expired	0[1]	47[4]	79.20[1]	565[4]	16.30[1]	116[4]	4.50[1]	32[4]	2
	Transported Gas									
4	In arterial blood	83(81-86)	47	0.975	573	19.6(17.3-22.3)	94	48.2(44.6-50.4)	40	B, 3;C, F-H, 2;D, E, 1, 4
5	In capillary blood	83(81-86)	47	0.975	573	±1 to 22.3[5]	±1 to 94[5]	±44.6 to 57.7[5]	±40 to 50	B, 3;C, 2; D, E, 4;F-1, a
6	In tissue fluid	83(81-86)	47	0.975	573	±0.185[5]	±30[5]	±3.046[5]	±50[5]	B, 3;C, 2; D, E, 4;F-1, 5
7	In venous blood	83(81-86)	47	0.975	573	12.9(11.0-16.1)[6]	40	54.8(51.0-57.7)[6]	46	B, 3;D, E, 4;C, F-1, 2

/1/ Dry air. Partial pressure in mm Hg = vol %/ 100 x 760 mm Hg (Dalton's law). /2/ Ambient air; slight variations exist. Vol % = 100 x (partial pressure in mm Hg)/ 760 mm Hg (Dalton's law). /3/ "Alveolar" air, actually last part of expired samples. /4/ Physiological air, normal temperature (37°C), and standard pressure (760 mm Hg). /5/ Variable, depending on blood flow, tissue activity and relation of sample to capillary length or field. /6/ Internal jugular.

Contributor: (a) McCutcheon, F. H.

References: [1] Krogh, A., "The Comparative Physiology of Respiratory Mechanisms," Philadelphia: Univ. of Pennsylvania Press, 1941. [2] Nims, L. F., in Fulton's "Textbook of Physiology," Philadelphia: W. B. Saunders Co., 1949. [3] Albritton, E. C., "Standard Values in Blood," Philadelphia: W. B. Saunders Co., 1952 (average from Table 67). [4] Albritton, E. C., "Standard Values in Blood," Philadelphia: W. B. Saunders Co., 1952 (average from Table 94). [5] Albritton, E. C., "Standard Values in Blood," Philadelphia: W. B. Saunders Co., 1952 (average from data for plasma, Table 94).

8. PRESSURE-DEPTH GRADIENT IN THE SEA

Hydrostatic pressure increases with depth at approximately 0.1 atmosphere per meter, the exact value being affected by salinity, temperature and latitude of the water. Salinity is expressed in parts per thousand (°/oo).

	Depth, m	Salinity, °/oo	Temperature, °C	Pressure, atm/m[1]	
				Latitude 30°	Latitude 60°
	(A)	(B)	(C)	(D)	(E)
1	0	32	0	0.099141	0.099403
2	0	32	20	0.098831	0.099092
3	0	35	0	0.099375	0.099638
4	0	35	20	0.099052	0.099314
5	5000	35	0	0.101757	0.102026
6	5000	35	5	0.101660	0.101929
7	10,000	35	0	0.103952	0.104225

/1/ 1 atmosphere = 1.01325 bars, 1.03327 kg/sq cm, 14.696 lb/sq in, 760 mm Hg.

Contributor: ZoBell, C. E.

9. PRESSURE EQUIVALENTS

	Atmospheres	mm Hg	Absolute lb/sq in	Gauge lb/sq in	Diving Depth ft
	(A)	(B)	(C)	(D)	(E)
1	1	760	14.7	0	0
2	2	1520	29.4	14.7	33
3	3	2280	44.1	29.4	66
4	4	3040	58.8	44.1	99
5	5	3800	73.5	58.8	132
6	6	4560	88.2	73.5	165
7	7	5320	102.9	88.2	198
8	8	6080	117.6	102.9	231
9	9	6840	132.3	117.6	264
10	10	7600	147.0	132.3	297

Contributor: Behnke, A. R.

10. PARTITION COEFFICIENTS OF VARIOUS GASES AT 37-38°C

Adapted from Kety, S. S., Pharm. Rev., Balt. 3:5, 1951.

Partition coefficient = the ratio at equilibrium in which a given substance (gas) distributes itself between two or more different solvents.

	Gas	Water/Gas	Blood/Gas	Tissue/Blood	Oil/Water	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Acetone		333.0			C, 1
2	Acetylene	0.850	0.795			B, 2;C, 3
3	Argon	0.0295			5.3	B-E, 4
4	Chloroform	4.6	7.3	1.1 (brain) 0.9 (liver)	110.0	B-C, 5;D, 6, 7;E, 8
5	Cyclopropane	0.204	0.457		35.0	B-E, 9
6	Divinyl ether	1.32			41.3	B-E, 10
7	Ethylene	0.089	0.140	1.2 (brain) 1.0 (heart)	14.4	B-C, 2;D, 11;E, 9
8	Ethyl ether	15.5	14.9	1.14 (brain)	3.2	B-C, 12;D, 13;E, 9
9	Helium	0.0097	0.0098		1.7	B, E, 4;C, 14
10	Hydrogen	0.018			3.1	B-E, 4
11	Krypton	0.051			9.6	B-E, a, b
12	Neon	0.011				B, 4
13	Nitrogen	0.0144	0.0147	1.1 (brain) 1.1 (liver) 5.2 (fat)	5.2	B-C, 15;D, 16, 17;E, 18
14	Nitrous oxide	0.440	0.466	1.0 (brain) 1.0 (heart)	3.2	B, 19;C-D, 20, 21;E, 9
15	Radon	0.17			125.0	B-E, 4
16	Xenon	0.097			20.0	B-E, 4

Contributors: Bartels, H., and Opitz, E.

References: [1] Widmark, E. M., Acta med. scand. 52:87, 1919. [2] Grollman, A., J. Biol. Chem. 82:317, 1929. [3] Taylor, H. L., and Chapman, C. B., Fed. Proc. 9:124, 1950. [4] Lawrence, J. H., Loomis, W. F., Tobias, C. A., and Turpin, F. H., J. Physiol. 105:197, 1946. [5] Moore, B., and Roaf, H. F., Proc. Roy. Soc., Lond. 73:382, 1904. [6] Nicloux, M., and Yovanovitch, A., C. rend. Soc. biol. 91:1285, 1924. [7] Tissot, M. J., ibid 60:195, 1906. [8] McCollum, J. L., J. Pharm. Exp. Ther. 40:305, 1930. [9] Orcutt, F. S., and Seevers, M. H., ibid 59:206, 1937. [10] Ruigh, W. L., Proc. Soc. Exp. Biol. 40:608, 1939. [11] Harmel, M. H., Pharm. Rev., Balt. 3:1, 1951. [12] Haggard, H. W., J. Biol. Chem. 55:131, 1923. [13] Haggard, H. W., ibid 59:771, 1924. [14] Hawkins, J. A., and Schilling, C. W., ibid 113:649, 1936. [15] Van Slyke, D. D., Dillon, R. T., and Margaria, R., ibid 105:571, 1934. [16] Campbell, J. A., and Hill, L., Quart. J. Exp. Physiol., Lond. 23:219, 1933. [17] Campbell, J. A., and Hill, L., J. Physiol. 71:309, 1931. [18] Tobias, C. A., Jones, H. D., Lawrence, J. H., and Hamilton, J. G., J. Clin. Invest. 28:1375, 1949. [19] Siebeck, R., Skand. Arch. Physiol., Berl. 21:368, 1909. [20] Kety, S. S., Harmel, M. H., Broomell, H. T., and Rhode, C. B., J. Biol. Chem. 173:487, 1948. [21] Eckenhoff, J. E., Hafkenschiel, J. H., Harmel, M. H., Goodale, W. T., Lubin, M., Bing, R. J., and Kety, S. S., Am. J. Physiol. 152:356, 1948.

11. DEPRESSION OF O_2 AND CO_2 SOLUBILITY BY VARIOUS SALTS IN WATER

$\Delta\alpha$ = solubility depression per unit M concentration of salt. Values of Δ are for salt concentrations up to 0.3 M.

	Salt	$\Delta\alpha O_2$	$\Delta\alpha CO_2$		Salt	$\Delta\alpha O_2$	$\Delta\alpha CO_2$
	(A)	(B)	(C)		(A)	(B)	(C)
1	Sodium chloride	0.0073	0.111	6	Sodium biphosphate		0.218
2	Potassium chloride	0.0069	0.087	7	Potassium biphosphate		0.185
3	Potassium fluoride	0.0078		8	0.155 M NaCl	0.00113[1]	0.0172[1]
4	Sodium bicarbonate	0.0081		9	0.119 M NaCl	0.00087[1]	0.0132[1]
5	Lactic acid	0.0003					

/1/ Corrections for physiological substitute-solutions.

Contributors: Bartels, H., and Opitz, E.

References: [Column B] Sendroy, J., Jr., Dillon, R. T., and Van Slyke, D. D., J. Biol. Chem. 105:597, 1934. [Column C] Van Slyke, D. D., Sendroy, J., Jr., Hastings, A. B., and Neill, J. M., ibid 78:765, 1928.

12. SOLUBILITY COEFFICIENTS: GASES

See Introduction for explanation of apparent discrepancies in values given in different parts of table.

Part I: IN WATER AT VARIOUS TEMPERATURES

Solubility coefficient: $\alpha = \frac{\text{ml gas}}{\text{ml liquid at 760 mm pressure}}$.

	Temp °C	αN_2[1]	αO_2	αH_2	αCO_2	αCO		Temp °C	αN_2[1]	αO_2	αH_2	αCO_2	αCO
	(A)	(B)	(C)	(D)	(E)	(F)		(A)	(B)	(C)	(D)	(E)	(F)
1	0	0.02354	0.04889	0.02148	1.713	0.03537	29	28	0.01376	0.02691	0.01720	0.699	0.02051
2	1	0.02297	0.04758	0.02126	1.646	0.03455	30	29	0.01358	0.02649	0.01709	0.682	0.02024
3	2	0.02241	0.04633	0.02105	1.584	0.03375	31	30	0.01342	0.02608	0.01699	0.665	0.01998
4	3	0.02187	0.04512	0.02084	1.527	0.03297	32	31[2]	0.01323	0.02574	0.01692	0.650	0.01974
5	4	0.02135	0.04397	0.02064	1.473	0.03222	33	32[2]	0.01304	0.02541	0.01686	0.636	0.01950
6	5	0.02086	0.04287	0.02044	1.424	0.03149	34	33[2]	0.01284	0.02507	0.01679	0.621	0.01925
7	6	0.02037	0.04180	0.02025	1.377	0.03078	35	34[2]	0.01265	0.02474	0.01673	0.607	0.01901
8	7	0.01990	0.04080	0.02007	1.331	0.03009	36	35	0.01256	0.02440	0.01666	0.592	0.01877
9	8	0.01945	0.03983	0.01989	1.282	0.02942	37	36[2]	0.01242	0.02413	0.01662	0.580	0.01857
10	9	0.01902	0.03891	0.01972	1.237	0.02878	38	37[2]	0.01227	0.02386	0.01657	0.567	0.01836
11	10	0.01861	0.03802	0.01955	1.194	0.02816	39	38[2]	0.01213	0.02360	0.01653	0.555	0.01816
12	11	0.01823	0.03718	0.01940	1.154	0.02757	40	39[2]	0.01198	0.02333	0.01648	0.542	0.01795
13	12	0.01786	0.03637	0.01925	1.117	0.02701	41	40	0.01184	0.02306	0.01644	0.530	0.01775
14	13	0.01750	0.03559	0.01911	1.083	0.02646	42	41[2]	0.01173	0.02262	0.01640	0.520	0.01758
15	14	0.01717	0.03486	0.01897	1.050	0.02593	43	42[2]	0.01162	0.02218	0.01636	0.510	0.01741
16	15	0.01685	0.03415	0.01883	1.019	0.02543	44	43[2]	0.01152	0.02175	0.01632	0.499	0.01724
17	16	0.01654	0.03348	0.01869	0.985	0.02494	45	44[2]	0.01141	0.02131	0.01628	0.489	0.01707
18	17	0.01625	0.03283	0.01856	0.956	0.02448	46	45[2]	0.01130	0.02187	0.01624	0.479	0.01690
19	18	0.01597	0.03220	0.01844	0.928	0.02402	47	46[2]	0.01122	0.02168	0.01621	0.470	0.01675
20	19	0.01570	0.03161	0.01831	0.902	0.02360	48	47[2]	0.01113	0.02148	0.01618	0.462	0.01660
21	20	0.01545	0.03102	0.01819	0.878	0.02319	49	48[2]	0.01105	0.02129	0.01614	0.453	0.01645
22	21	0.01522	0.03044	0.01805	0.854	0.02281	50	49[2]	0.01096	0.02109	0.01611	0.445	0.01630
23	22	0.01498	0.02988	0.01792	0.829	0.02244	51	50	0.01088	0.02090	0.01608	0.436	0.01615
24	23	0.01475	0.02934	0.01779	0.804	0.02208	52	60	0.01023	0.01946	0.01600	0.359	0.01488
25	24	0.01454	0.02881	0.01766	0.781	0.02174	53	70	0.00977	0.01833	0.0160		0.01440
26	25	0.01434	0.02831	0.01754	0.759	0.02142	54	80	0.00958	0.01761	0.0160		0.01430
27	26	0.01413	0.02783	0.01742	0.738	0.02110	55	90	0.0095	0.0172	0.0160		0.0142
28	27	0.01394	0.02736	0.01731	0.718	0.02080	56	100	0.0095	0.0170	0.0160		0.0141

/1/ Atmospheric nitrogen = 98.815% by vol nitrogen + 1.185% by vol air. /2/ Values for these temperatures were obtained by graphic or calculated interpolation.

Contributors: Bartels, H., and Opitz, E.

Reference: Hodgman, C. D., "Handbook of Chemistry and Physics," p 1532, Cleveland: Chemical Rubber Publishing Co., 1952.

Part II: O_2 AND CO_2 IN PHYSIOLOGICAL FLUIDS AT VARIOUS TEMPERATURES

N = normal.

	Temp oC	aO2[1]			aCO2[1]			Temp oC	aO2[1]			aCO2[1]	
		0.155 N NaCl[2]	0.119 N NaCl[2]	Whole Blood[3]	0.155 N NaCl[4]	0.119 N NaCl[4]			0.155 N NaCl[2]	0.199 N NaCl[2]	Whole Blood[3]	0.155 N NaCl[4]	0.199 N NaCl[4]
	(A)	(B)	(C)	(D)	(E)	(F)		(A)	(B)	(C)	(D)	(E)	(F)
1	10	0.03689	0.03715		1.177	1.181	17	26	0.02670	0.02696	0.0300	0.721	0.725
2	11	0.03605	0.03631		1.137	1.141	18	27	0.02623	0.02649	0.0293	0.701	0.705
3	12	0.03524	0.03550		1.100	1.104	19	28	0.02578	0.02604	0.0285	0.682	0.685
4	13	0.03446	0.03472		1.066	1.070	20	29	0.02536	0.02562	0.0279	0.665	0.669
5	14	0.03373	0.03399		1.033	1.037	21	30	0.02495	0.02521	0.0273	0.648	0.652
6	15	0.03302	0.03328		1.002	1.006	22	31	0.02461	0.02487	0.0267	0.633	0.637
7	16	0.03235	0.03216		0.968	0.972	23	32	0.02428	0.02454	0.0261	0.619	0.623
8	17	0.03170	0.03196		0.939	0.943	24	33	0.02394	0.02420	0.0257	0.604	0.608
9	18	0.03107	0.03133		0.911	0.915	25	34	0.02361	0.02387	0.0252	0.590	0.594
10	19	0.03048	0.03074		0.885	0.889	26	35	0.02327	0.02353	0.0247	0.575	0.579
11	20	0.02989	0.03015	0.0344	0.861	0.865	27	36	0.02300	0.02326	0.0241	0.563	0.567
12	21	0.02931	0.02957	0.0337	0.837	0.841	28	37	0.02273	0.02299	0.0237	0.550	0.554
13	22	0.02875	0.02901	0.0329	0.812	0.816	29	38	0.02247	0.02273	0.0232	0.538	0.542
14	23	0.02821	0.02847	0.0321	0.787	0.791	30	39	0.02220	0.02246	0.0228	0.523	0.529
15	24	0.02768	0.02794	0.0312	0.764	0.768	31	40	0.02193	0.02219	0.0223	0.513	0.517
16	25	0.02718	0.02744	0.0306	0.742	0.746							

/1/ Calculated from Reference [1] . /2/ The decrease in solubility through addition of salt was calculated according to the data of Sendroy, Dillon, and Van Slyke [2] . /3/ The values for blood were calculated through graphic interpolation from Figure 3 of Sendroy, Dillon, and Van Slyke [2] . /4/ The decrease in solubility through addition of salt was calculated according to the data of Van Slyke, Sendroy, Hastings, and Neill [3] .

Contributors: Bartels, H., and Opitz, E.

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12. SOLUBILITY COEFFICIENTS: GASES (Concluded)

See Introduction for explanation of apparent discrepancies in values given in different parts of table.

Part III: IN VARIOUS FLUIDS AND TISSUES

For tissues, $\alpha = \dfrac{\text{ml gas}}{\text{g tissue at 760 mm pressure}}$

	Medium	Source	Temp, °C	αN_2	αO_2	αH_2	αCO_2	αHe	αN_2O	αC_2H_4	αC_2H_2	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
1	Water		25	0.01483	0.02831	0.01754	0.759		0.549	0.108		D, 1;E, 2;F, 3;G, 4;I-J, 5
2			37.5							0.078	0.747	J-K, 6
3			38	0.01272	0.02323	0.01620	0.545	0.0085				D, 1;E, 7;F, 8;G, 9;H, 10
4	0.155 N NaCl		25	0.01409								D, 1
5			38	0.01220	0.02211	0.01559	0.529					D, 1;E, 7;F, 8;G, 9
6	Whole blood	Man	37		0.02356[1]				0.412			E, 11, 12;I, 10
7					0.0214+[2]							E, 11, 12
8			37.5							0.123	0.740	J-K, 6
9			38				0.494[3, 4]					G, a
10							0.492[3, 5]					G, a
11							0.488[1, 3]					G, a
12							0.485[3, 6]					G, a
13							0.482[3, 7]					G, a
14		Myeloid leukemia	37.5								0.735	K, 6
15		Polycythemia	37.5								0.710	K, 6
16		Dog	37						0.425			I, 13
17			37.5							0.141	0.759	J-K, 6
18			38					0.0088[1]				H, 10
19		Ox	38	0.0130[1]	0.0230[1]	0.0149[1]	0.471[1]	0.0088				D, 1;E, 7;F, 8;G, 9;H, 10
20				0.0117+[8]	0.0209+[2]							D, 1;E, 7
21		Rabbit	37.5							0.128	0.703	J-K, 6
22	Plasma	Man	37		0.0214		0.526[9]					E, 11, 12;G, a
23			38				0.510					G, 8
24		Lipemia	38				0.552					G, 8
25		Dog	37.5								0.690	K, 6
26		Ox	38	0.0117	0.0209	0.01533	0.510					D, 1;E, 7;F, 8;G, 9
27	Erythrocytes	Dog	37.5								0.778	K, 6
28		Ox	38	0.0146	0.0261	0.01454	0.44					D, 1;E, 7;F, 8;G, 9
29	Urine	Man	38				0.522					G, 14
30	Heart	Man	37						0.446			I, 15
31		Dog	37						0.447			I, 15
32	Brain	Man	37						0.437			I, 15
33		Dog	37						0.437			I, 15
34		Sheep	37	0.0162								D, 16
35	Liver	Sheep	37	0.0162								D, 16
36	Connective tissue	Dog	22				0.73					G, 17
37		Frog	20				0.73					G, 18
38	Skeletal muscle	Dog	22				0.78					G, 17
39		Frog	22				0.78					G, 19-21

40	Smooth muscle	Cat	22				0.78					G, 17
41	Nerve	Frog	22				0.78					G, 19-21
42	Skin	Frog	22				0.73					G, 17
43	Gelatin, 20%		15				1.0					G, 22
44	Cottonseed oil		22			0.042	1.34					F, G, 23
45			40		0.12	0.05	0.876					E-G, 24
46	Olive oil		22	0.052				0.015				D, 25;H, 26
47			37	0.067				0.015				D, 27;H, 26
48			38		0.112							E, 28
49	Rubber		17				0.86					G, 29
50			22				0.93					G, 17

/1/ 20 volume % O_2 capacity. /2/ Whole blood with different O_2 capacity + factor (0.000108) for 1.0 volume % O_2. /3/ Calculated according to the data of Van Slyke, Sendroy, Hastings, and Neill [8]. /4/ 16 volume % O_2 capacity. /5/ 18 volume % O_2 capacity. /6/ 22 volume % O_2 capacity. /7/ 24 volume % O_2 capacity. /8/ Whole blood with different O_2 capacity + factor (0.000064) for 1.0 volume % O_2. /9/ Calculated according to diagram of Keys, A., Hall, F. G., and Guzman Barron, E. S., Am. J. Physiol. 115:292, 1936.

Contributors: (a) Bartels, H., and Opitz, E., (b) Behnke, A. R.

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13. DIFFUSION COEFFICIENTS AND PERMEATION COEFFICIENTS

D = "true" diffusion coefficient in sq cm/min ($\frac{\partial c}{\partial t} = -D\frac{\partial^2 c}{\partial x^2}$); c = concentration in ml gas (STPD) dissolved per ml liquid; t = time in min; x = distance in cm. D' = permeation coefficient in sq cm/min/atm: volume of gas (ml, STPD) diffusing per unit time (min), area (sq cm), and thickness (cm), if the difference in partial pressure of the diffusing gas is 1 atm in the direction of the gas flow. $D = \frac{D'}{\alpha}$, where α is the Bunsen solubility coefficient, ml gas (STPD) dissolved per ml liquid at a partial pressure of 1 atm. The temperature coefficient of D in the range 15-40°C is in most cases nearly 2% °C [1,2], and temperature coefficient of D' nearly 1% per °C in the same range. [3]

Part 1: O_2 AND CO_2 IN VARIOUS FLUIDS AND TISSUES

Unless otherwise stated, values of D and D' were recalculated from data in the references, with the aid of solubility coefficients given in these tables.

	Substance	Temp, °C	D x 10^{-4}	α	D' x 10^{-5}	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
	Oxygen					
1	Water	25	15.1	0.0283	4.3	B-E, 2
2	Water	37	19.3	0.0239	4.6	B-E, 2
3	Serum[1]	25	11.9	0.025	3.0	B-C, 2;D, 4, 5;E, a, b
4	Serum	37	15.25	0.021	3.2	B-C, 2;D, 4, 5;E, a, b
5	Serum protein solution, 8%[2]	25	11.1	0.025	2.8	B-C, 6,7;D,calc. by a,b from 4,5;E,a,b
6	Methemoglobin solution, 8%[2]	25	11.2	0.025	2.8	B-C, 8;D, calc. by a, b from 4,5; E,a,b
7	Serum protein, 30%	25	4.6			B-C, 6, 7
8	Methemoglobin, 30%[3]	25	5.5	0.032	1.8	B-C, 8;D, calc. by a,b from 4,5; E, a, b
9	Muscle, frog	20	4.5	0.031[4]	1.4	B-C, E, 3;D, 4, 5, 9
10	Muscle, frog	37	7.0	0.0235[4]	1.65[5]	B-C, a, b;D, 4, 5;E, 3
11	Connective tissue, frog	20	3.7	0.031[4]	1.15	B-C, E, 3;D, 4, 5
12	Connective tissue, dog	37	5.75	0.0235[4]	1.35[6]	B-C, a, b;D, 4, 5;E, 3
13	Chitin	20			0.13	B, E, 3
14	Gelatin, 15%	20			2.8	B, E, 3
15	Rubber	17	0.57			B-C, 10
16	Rubber	20			0.77	B, E, 3
	Carbon Dioxide					
17	Water	20	10.65[7]	0.878[8]	93.5	B-E, 11, 12
18	Water	37	15.38			B-C, calc. by a, b from 11, 12
19	Muscle, frog	22	11.7[7]	0.78	91.0	B-C, 13;D, 14;E, a, b
20	Muscle, frog	22	6.8	0.78[7]	53.0[7]	B-C, a, b;D-E, 14
21	Muscle, dog	22	6.0	0.78[7]	47.0[7]	B-C, a, b;D-E, 14
22	Muscle, smooth, cat	22	6.4	0.78	50.0[7]	B-C, a, b;D-E, 14
23	Connective tissue, frog	20	5.3	0.77[7]	41.0[7]	B-C, a, b;D, 14;E, 3
24	Diaphragm, dog	22	3.6	0.73[7]	26.5	B-C, a, b;D-E, 14
25	Nerve	22	0.71[7]	0.78	5.5	B-C, 13;D, 14;E, a, b
26	Skin, frog	22	4.2	0.73[7]	30.5[7]	B-C, a, b;D-E, 14
27	Skin, acidified	22	5.7	0.78[7]	44.7[7]	B-C, a, b;D-E, 14
28	Rubber	17	0.51[7]	0.93	4.8	B-C, 10;D-E, a, b
29	Rubber	22	0.51	0.93[7]	4.8[7]	B-C, E, a, b;D, calc. by 14 from 15

/1/ Solubility of O_2 at 25°C was calculated from the value for whole blood [5] and the ratio $\frac{\alpha \text{ serum}}{\alpha \text{ whole blood}} = 0.908$ [4]. /2/ For the solubility coefficient of O_2 in 8% serum protein solution and in 8% methemoglobin solution, the value for serum was taken [4]. /3/ For the solubility coefficient of O_2 in 30% methemoglobin, the value for erythrocytes [4] was taken. /4/ Solubility of whole blood was used [4, 5] as the partition coefficient ($\frac{\alpha \text{ tissue}}{\alpha \text{ blood}}$) for most gases is too close to 1.0 [9]. /5/ Value for D' is calculated from 9 E, assuming a temperature coefficient for D' of 1% per °C [3]. /6/ Value for D' is calculated from 11 E, assuming a temperature coefficient for D' of 1% per °C [3]. /7/ Value directly determined. /8/ Value for D is calculated from 17 C by assuming a rise of D by 2% per °C [2, 11].

Contributors: (a) Bartels, H., (b) Opitz, E.

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DIFFUSION COEFFICIENTS AND PERMEATION COEFFICIENTS (Concluded)

Part II: VARIOUS GASES RELATIVE TO O_2 AS UNITY

$\frac{D\ gas}{D\ O_2}$ or $\frac{D'\ gas}{D'\ O_2}$. Absolute values for O_2 obtained from Part I of this table.

	Substance	Temp °C	Absolute Value O_2	H_2		He		N_2		CO		CO_2		Reference
				D	D'	D	D'	D	D'	D	D'	D	D'	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)
1	Water	20	$D = 13.7 \times 10^{-4}$	1.62				0.91		0.94				D,H,1;J,2
2			$\alpha = 0.0239$											
3			$D' = 3.3 \times 10^{-5}$								0.89		31.8	K,2;M,1
4		37	$D = 19.3 \times 10^{-4}$	1.57		1.97		0.93				0.62		D,F,H,1;L,3
5			$\alpha = 0.02386$									1.33		L,1
6			$D' = 4.6 \times 10^{-5}$		1.09		0.69		0.483				14.5	E,G,I,M,a,b
7	Serum	37	$D = 15.24 \times 10^{-4}$	1.54				0.85						D,H,1
8			$\alpha = 0.021$											
9			$D' = 3.2 \times 10^{-5}$		1.118				0.479					E,I,4
10	Muscle	16-20	$D = 4.5 \times 10^{-4}$									1.37		L,5
11			$\alpha = 0.031$											
12			$D' = 1.4 \times 10^{-5}$						0.60		0.70		35.0	I,K,M,2
13	Connective	16-20	$D = 3.7 \times 10^{-4}$									0.97		L,5
14	tissue		$\alpha = 0.031$											
15			$D' = 1.15 \times 10^{-5}$						0.46		0.75		36.0	I,K,M,2
16													23.0	M,2
17	Rubber	16-17	$D' = 0.77 \times 10^{-5}$						0.52		0.56		5.0	I,K,M,2
18					2.15				0.39		0.44		5.3	E,I,K,M,6

Contributors: (a) Bartels, H., (b) Opitz, E.

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14. DIFFUSION COEFFICIENTS: GASES IN WATER AT VARIOUS TEMPERATURES

Methods: U = unspecified; A = measurement of the volume of gas diffusing per unit time into a gel of 1-2% agar in water, in temperature range 0-30°C; B = measurement of the volume of gas diffusing from a gas bubble into the surrounding water in the temperature range 21-37°C (the relative values of the coefficients for various gases obtained by this method were converted to absolute values by means of D_{H_2} as measured directly [1]); C = colorimetric measurement of the diffusion velocity of O_2 by addition of 0.03-1% hemaglobin as indicator; D = measurement of the volume of gas diffusing per unit time into a tube filled with gas-free water; P = polarographic measurement with the dropping-mercury electrode; T = measurement of the velocity of diffusion within a tube of 1 cm diameter filled with water or a 2% solution of agar in water.

	Gas	Method	D x 10^{-4}, sq cm per min					Reference
			10°C	20°C	25°C	30°C	37°C	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	H_2	A	16.65	21.75	24.3	26.85	30.4	1
2		B		22.2	24.3	26.8	30.3	2
3	He	B					37.2	2
4	C_2H_2	A	8.75	10.95	12.08	13.2	14.77	1
5	N_2	A	8.2	10.05	11.0	11.93	13.2	1
6		T		11.6				3, 4
7		U		11.9				3, 4
8		B		12.5	14.2	15.5	18.0	2
9	CO	U		6.1				5
10				13.1				6
11	O_2	U		10.9				3, 4
12				12.35				3, 4
13		B		13.7	15.1	16.8	19.3	2
14		P			15.6			7
15		C, P			13.5			8-10
16	CO_2	A	7.48	9.14	9.98	10.82	12.03	1
17		B			14.8	16.3	18.9	11
18		U	8.76	10.6				3, 4, 12
19		D		9.5				5
20	N_2O	T	9.23	10.0				3
21		B, D		9.2				5

Contributors: Bartels, H., and Opitz, E.

References: [1] Tammann, G., and Jessen, V., Zschr. anorgan. u. allgem. Chem. 179:125, 1929. [2] Gertz, K. H., and Loeschcke, H. H., Zschr. Naturforsch. 9b:1, 1954. [3] Hüfner, G., Wied. Ann. Physik. 60:134, 1897. [4] Bruins, H. R., International Critical Tables, vol V, p63, New York: McGraw-Hill, 1929. [5] Longmuir, J. S., and Roughton, F. J., J. Physiol., Lond. 118:264, 1952. [6] Krogh, A., ibid 52:391, 1919. [7] Kolthoff, J. M., and Miller, C. S., J. Am. Chem. Soc. 63:101, 1941. [8] Kreuzer, F., Helvet. physiol. pharm. acta 8:505, 1950. [9] Kreuzer, F., ibid 9:388, 1951. [10] Pircher, L., ibid 10:110, 1952. [11] Gertz, K. H., and Loeschcke, H. H., Zschr. Naturforsch. 11b:61, 1956. [12] Carlson, T., J. Am. Chem. Soc. 33:1027, 1911.

15. DEVELOPMENT OF THE RESPIRATORY SYSTEM: MAN

This table must be used with discretion because of certain discrepancies between embryological terminology and fact. The changes which constitute development are continuous but must be described in discontinuous units of time, anatomical or functional characteristics, stages or events. Although the descriptions are consequently arbitrary, they are not necessarily standardized, for many have units which are unmeasurable, unreliable, estimated, omitted, qualified or used in different senses by different authors. These defects have been obscured by conversion of descriptions into symbols in order to emphasize essential features and reveal the quite regular sequence of events. Differences in width of columns do not indicate time or age relationships, but are merely space accommodations for the numerical headings. Capital letters show pattern of general development, small letters the development of specific anatomic features. Letters with connecting dashes are ranges. A = anlage, primordium, condensation, appearance; first becomes distinct. B = becomes increasingly characteristic or distinct; differentiation. C = completion of basic plan. D = degeneration, dwindling, decrease, atrophy, regression, lag. E = eruption, perforation, opening. F = fusion, closure, joining, anastomosis. I = ingrowth, invasion, intrusion or depression below free surface, groove, regional growth difference. L = lengthwise subdivision, lobulation, lamination, splitting, branching. o = ossification; c = appearance of cilia; ch = chondrification; e = appearance of elastic tissues; g = appearance of glands; j = formation of joint-cavities; m = appearance of muscle fibers; n = innervation established; w = excavation of bone.

	Structure	Germ Layer[1]			Streeter's Horizons[2]													Weeks after Fertilization													After Birth					
		Ecto-derm	Meso-derm	Ento-derm	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	8	9	10	12	14	16	18	20	24	28	32	36	38	mo 1	mo 2	yr 2	yr 4	yr 6	yr 8
1	Nose	*	*				A		I			E-	-E[3]	ch-	-ch																					
2	Nasal epithelium	*								B		n						g- c-	g c																	
3	Vomero-nasal organ	*								A-		-A	I				D--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4	Nasal-lacrimal duct	*										I														E-					-E					
5	Maxillo-turbinal		*							A-			-A				ch-		-ch					o-		-o										
6	Ethmo-turbinals (in order)		*								A-						-A	ch-		-ch							o-		-o							
7	External nares	*											F-	-F						E-		-E														
8	Sinus, maxillary	*																A-		-A									w-	-w						
9	Sphenoidal	*																				A-		-A							w-	-w				
10	Ethmoidal	*																					A-		-A				w-	-w						
	Frontal																																			
11	Horizontal part	*																						A-		-A							w-	-w		
12	Vertical part	*																						A-		-A								w-		-w
13	Larynx		*	*				B	F-		-F	L-	ch-	m-	ch m		-L	C	c-	-c	g-	-g				j-	-j									
14	Epiglottis		*	*							A-	-A									g-	-g	ch-		-ch											
15	Lung		*	*	A	J																														
16	Trachea		*	*			K-	K		m-	-m			ch-	ch			g- c-		g c	e															
17	Primary bronchi		*	*			K-	K		m-	-m				ch-	ch			g- c-	g c	e															
18	Lobar bronchi		*	*				A-	-A	m-	-m					ch-	-ch			g- c-	g c e-	e														
19	Segmental bronchi		*	*							A-	-A m-	m						ch-		ch g- c- e-	g c e														
20	Subsegmental bronchi		*	*								A-	-A m-	m							ch-	ch														

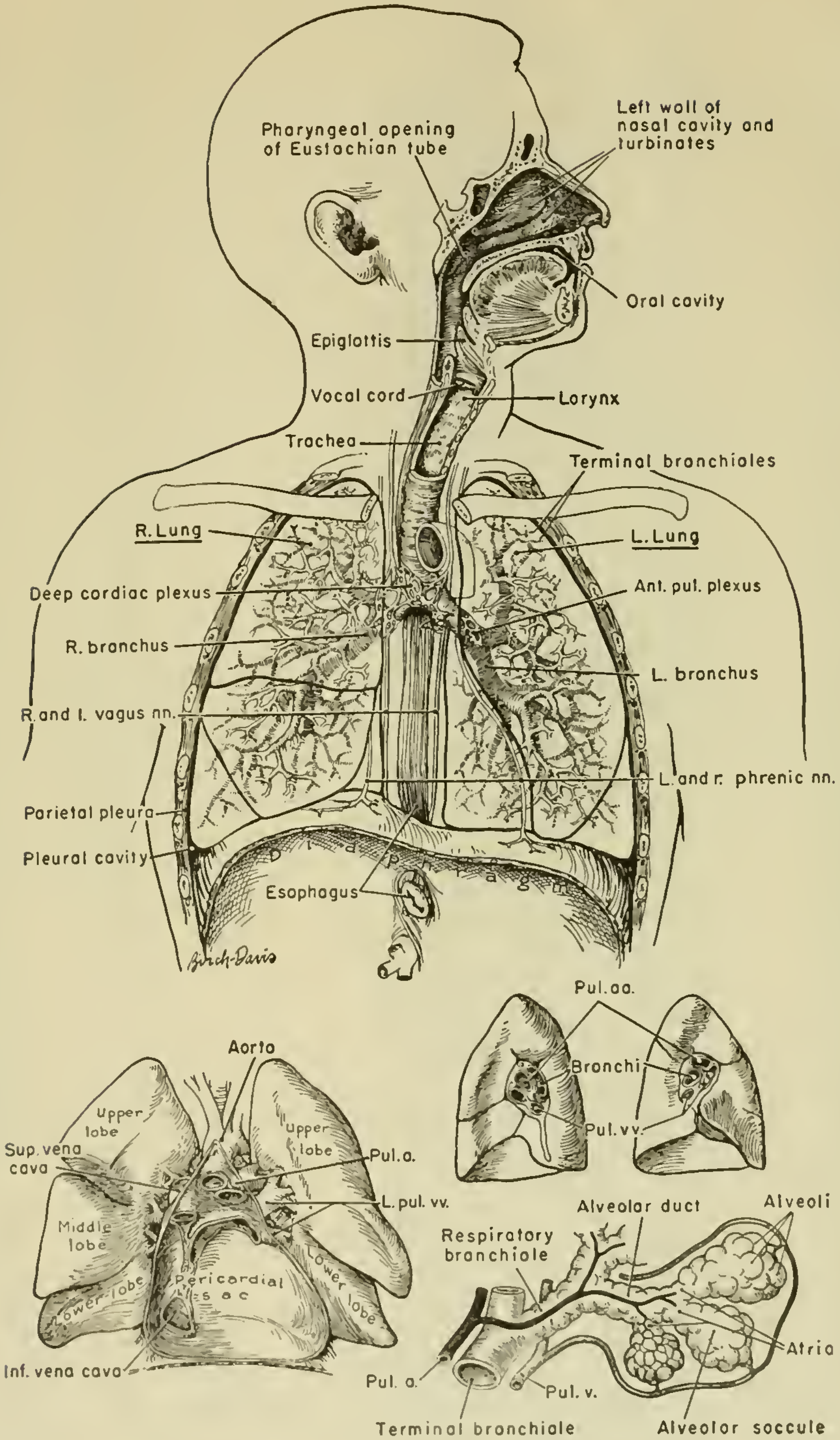
21	Alveolar ducts	*	*																						A-e	A e											
22	Alveolar sacs, terminal alveoli	*	*																										A-	--	A						

/1/ All germ layers of parenchyma become distinct at Stage IV, Streeter's horizons. /2/ Use of Streeter's horizons as units for the first seven weeks, is an attempt to minimize discrepancies arising from uncertain age determination and individual rate of development. /3/ Choanae.

Contributors: (a) Bõving, B. G., (b) Towers, B.

General References: NOSE AND ACCESSORY SINUSES. Coffin, L., Am. J. M. Sc. 129:297, 1905. Hochstetter, F., Verh. Anat. Ges. ?:181, 1892. Peter, K., "Atlas det Entwicklung der Nase und des Gaumens beim Menschen, mit Einschluss der Entwicklungsstorungen," Jena: Gustav Fischer, 1913. Schaeffer, J. P., Am. J. Anat. 10:313, 1910. Schaeffer, J. P., J. Morph. 21:613, 1910. Schaeffer, J. P., "The Embryology, Development and Anatomy of the Nose, Paranasel Sinuses, Nasolacrimal Passageways and Olfactory Organ in Man," Philadelphia: Blakiston, 1920. Streeter, G. L., series on "Developmental Horizons," Carnegie Institution, Washington, D. C. Towers, B., unpublished. LARYNX. Frazer, J. E., J. Anat., Lond. 44:156, 1910. Grosser, O., "Keibel and Mall's Manual of Human Embryology," Philadelphia: Lippincott, 1912. Kallius, E., Anat. Hefte Bd. 9:301, 1897. Nicolas, A., Bibliogr. Anatomique 2:176, 1894. Streeter, G. L., series on "Developmental Horizons," Carnegie Institution, Washington, D. C. Towers, B., unpublished. LUNG. Amprino, R., Arch. ital. anat. 38:447, 1937. Boyden, E. A., "Segmental Anatomy of the Lungs," p 276, New York: McGraw-Hill Co., 1955. De Leonardis, L., Arch. ital. anat. 55:383, 1950. De Leonardis, L., ibid 58:127, 1953. Dubreuil, G., Lacoste, A., and Raymond, R., Bull. histo. appl., Lyon 13:235, 1936. Grosser, O., "Keibel and Mall's Manual of Human Embryology," Philadelphia: Lippincott, 1912. Heiss, R., Arch. Anat. u. Physiol. Anat. Abt., Jahrg. 1919, p 1. His, W., ibid, Jahrg. 1887, p 89. Keibel, F., and Elze, C., "Normentafein zur Entwicklungsgeschichte des Menschen," p 314, Jenna: Gustav Fischer, 1908. Lenzi, L., Monit. zool. ital. 9:213, 1898. Linser, P., Anat. Hefte 13:307, 1900. Lopez, A., Arch. españ. morf. 2:123, 1954. Potter, E. L., and Loosli, C. G., Am. J. Dis. Child. 82:226, 1951. Puiggros-Sala, J., Zschr. Anat. Entw. 106:209, 1936. Quénu, L., and Quéreux, P., Congres federatif international d'anatomic, Résumés, p 185, 1955. Streeter, G. L., series on "Developmental Horizons," Carnegie Institution, Washington, D. C. Towers, B., unpublished. Wells, L. J., and Boyden, E. A., Am. J. Anat. 95:163, 1954.

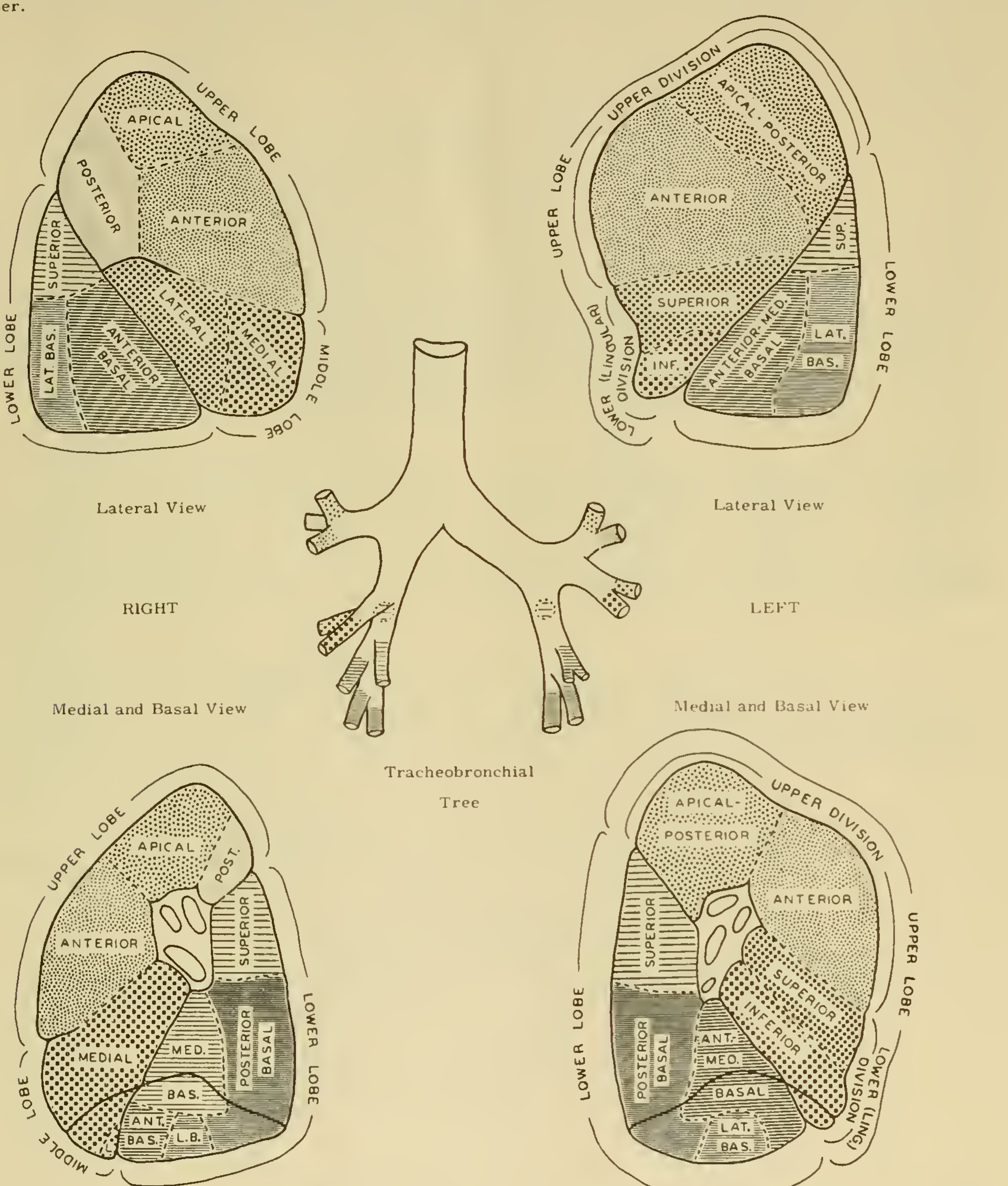
16. THE RESPIRATORY SYSTEM: MAN



Reference: "Dorland's Illustrated Medical Dictionary," 23rd ed., p 1355, Philadelphia: W. B. Saunders Co., 1957.

17. BRONCHOPULMONARY SEGMENTS: MAN

For practical purposes, the lungs may be divided into lobes which are fairly constant and well recognized, and each lobe into segments. These segments are supplied by the principal subdivisions of the bronchus entering that lobe. There is a fair degree of constancy in these bronchial subdivisions, both with respect to their point of origin in the tracheobronchial tree and to the part of lung which they supply. Terminology used is that suggested by Jackson and Huber.



Contributors: Jackson, C. L. and Huber, J. F.
Reference: Jackson, C. L., and Huber, J. F., Dis. Chest 9:319, 1943.

18. LUNG WEIGHT: MAN

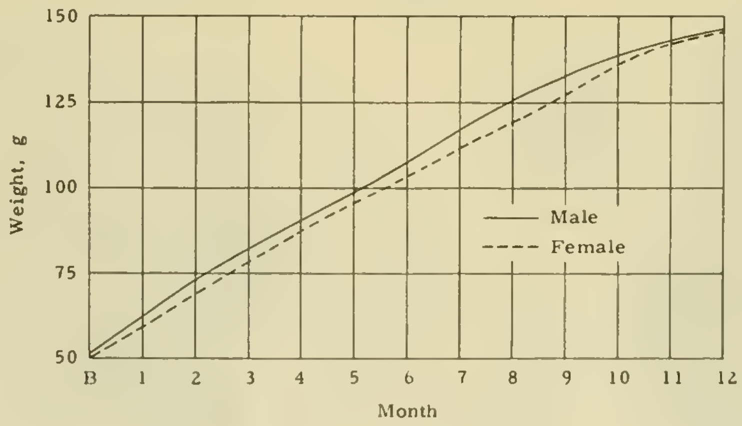
Age is given in years, unless otherwise specified. Values are mean weight for both lungs. Data collated by Scammon, R. E.

		Male		Female		Both Sexes	
	Age	Specimens no.	Lung Weight g	Specimens no.	Lung Weight g	Specimens no.	Lung Weight g
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Birth	92	51.7	71	50.9	232	50.0
2	Birth-3 mo	46	68.8	47	63.6	93	66.2
3	3-6 mo	53	94.1	52	93.3	113	94.2
4	6-9 mo	72	128.5	55	114.7	127	122.6
5	9-12 mo	49	142.4	63	142.1	115	142.7
6	1-2	78	170.3	84	175.3	166	173.7
7	2-3	76	245.9	62	244.3	145	243.8
8	3-4	51	304.7	34	265.5	88	286.5
9	4-5	32	314.2	21	311.7	56	310.8
10	5-6	18	260.6	27	319.9	51	301.9
11	6-7	8	399.5	17	357.5	29	377.6
12	7-8	15	365.4	10	404.4	25	381.0
13	8-9	5	405.0	7	382.1	14	400.7
14	9-10	5	376.4	5	358.4	11	342.2
15	10-11	15	474.5	4	571.2	20	495.7
16	11-12	8	465.6	4	535.0	12	488.7
17	12-13	4	458.8	3	681.7	7	554.3
18	13-14	6	504.5	4	602.3	12	521.8
19	14-15	12	692.8	6	517.0	19	632.1
20	15-16	12	691.7	13	708.8	28	702.4
21	16-17	9	747.3	6	626.5	15	699.0
22	17-18	12	776.9	13	694.5	25	734.0
23	18-19	20	874.7	15	654.9	35	780.5
24	19-20	19	1035.6	12	785.2	31	938.7
25	20-21	13	935.0	28	792.8	42	848.8
26	20-40	259	1169.3	150	885.5	410	1065.4

Contributor: Boyd, E.
Reference: Boyd, E., "Outline of Physical Growth and Development," Table 17, Minneapolis: Burgess, 1941.

19. LUNG WEIGHT INCREMENTS DURING FIRST YEAR: MAN

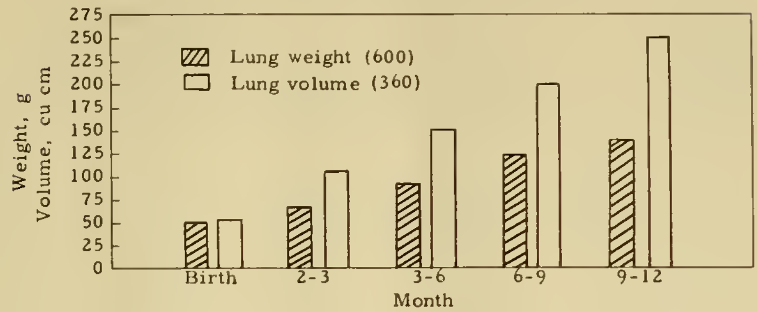
Data represent mean value at birth and for each trimester of first year, as determined from 600 observations collated from the literature and the author's own investigations. B = birth.



Reference: Krogman, W. M., Tabulae Biologicae 20:669, 1941 (adapted from Scammon, R. E., Radiology 9:93, 1927).

20. LUNG WEIGHT AND VOLUME INCREMENTS DURING FIRST YEAR: MAN

Figures in parentheses are total number of observations.



Reference: Krogman, W. M., Tabulae Biologicae 20:669, 1941 (adapted from Scammon, R. E., Radiology 9:101, 1927).

21. DIMENSIONS OF TRACHEOBRONCHIAL TREE: MAN, ADULT

Values tabulated below represent average dimensions of the adult tracheobronchial tree, computed by Findeisen and Landahl, according to a functional concept of structure rather than a strictly anatomical description. Here, the major bronchi are listed according to their order of generation rather than to lobar or segmental distribution. This table serves two purposes: First, it permits listing bronchi of similar size in the same category, and second, it serves as a tool for the functional description of airflow characteristics at various points of the tracheobronchial tree. However, the user of these values must recognize that there is considerable overlapping of the various orders of branching.

	Segment	Branches no.		Length cm		Diameter mm	
		Findeisen	Landahl	Findeisen	Landahl	Findeisen	Landahl
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Trachea	1	1	11.0	12.0	13.0	16.0
	Bronchi						
2	Primary (main)	2	2	6.5	6.0	7.5	10.0
3	Secondary	12	12	3.0	3.0	4.0	4.0
4	Tertiary	100	100	1.5	1.5	2.0	2.0
5	Quartenary	770	770	0.5	0.5	1.5	1.5
	Bronchioles						
6	Terminal	5.4×10^4	6×10^4	0.3	0.3	0.6	0.6
7	Respiratory	1.1×10^5	1.5×10^5	0.15	0.15	0.5	0.4
	Alveolar ducts						
8	1st order	2.6×10^7	3×10^7	0.02	0.05	0.2	0.3
9	2nd order		4×10^7		0.03		0.25
10	Alveolar sacs	5.2×10^7	10^8	0.03	0.033	0.3	0.33

Contributor: Ross, B. B.

References: [1] Findeisen, W., Pflügers Arch. 236:367, 1935. [2] Landahl, H. D., Bull. Math. Biophys. 12:43, 1950.

22. DIAMETER OF RESPIRATORY ALVEOLI: MAN

Values are in millimeters.

	Age	Diameter
	(A)	(B)
1	Few hr	0.05
2	1-1 1/2 yr	0.10
3	3-4 yr	0.12
4	5-6 yr	0.14
5	10-15 yr	0.17
6	18-20 yr	0.20
7	25-40 yr	0.22
8	50-60 yr	0.30
9	70-80 yr	0.34

Contributor: Boyd, E.

Reference: Scammon, R. E., in "Pediatrics," (Abt, I. A., ed.), vol I, p 257, Philadelphia: W. B. Saunders Co., 1923.

23. LENGTH OF BRONCHI: MAN

Values are in millimeters.

	Age	Main Right Bronchus	Right Upper Lobe Bronchus	Portion between Upper and Middle Lobe Bronchi	Left Main Bronchus
	(A)	(B)	(C)	(D)	(E)
1	1 mo	9	4	8	21
2	3 mo	10	5	10	24
3	5 mo	8	4.5	10	21
4	6 mo	10	6	11	25
5	1 yr	11	5	12	29
6	2 yr	13	6	11	29
7	3 yr	13	6	12	31
8	4 yr	12	7	12	32
9	5 yr	13.5	7	14	34
10	7 yr	11	10	17	33
11	10 yr	14	10	13	35
12	13 yr	22	10	19	42
13	40 yr	20	13	22	52

Contributor: Boyd, E.

Reference: Engel, S., Arch. Kinderh. 60:267, 1913.

24. DIAMETER OF TRACHEA AND BRONCHI: MAN

Values are in millimeters.

	Age	No.	Trachea		Right Bronchus		Left Bronchus	
			Sagittal	Frontal	Sagittal	Frontal	Sagittal	Frontal
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	1 mo	2	5.65	6.45	4.6	5.0	3.9	4.15
2	3 mo	1	6.5	6.8	5.0	4.7	4.0	4.1
3	5 mo	1	7.0	7.2	6.1	5.9	4.9	4.3
4	1 yr	2	7.0	7.9	5.9	6.25	4.4	5.1
5	$1\frac{1}{2}$ yr	1	8.0	10.4	7.7	7.8	4.7	7.3
6	2 yr	1	9.4	8.8	7.5	7.3	4.9	5.2
7	$2\frac{1}{2}$ yr	1	8.6	8.9	6.6	6.5	5.5	5.0
8	3 yr	1	10.8	9.4	7.4	7.3	7.0	5.5
9	$3\frac{1}{2}$ yr	1	9.0	10.7	7.0	8.2	5.0	7.6
10	4 yr	1	9.1	11.2	8.4	9.1	6.0	6.8
11	5 yr	2	10.25	9.7	8.55	7.5	6.3	6.95
12	7 yr	1	10.4	11.0	9.0	9.3	6.9	8.2
13	$7\frac{1}{2}$ yr	1	11.4	11.6	10.4	9.3	7.2	7.8
14	10 yr	1	9.3	12.4	8.6	9.2	7.3	8.4
15	13 yr	1	10.7	13.5	9.6	10.9	8.5	8.5
16	40 yr	1	16.7	14.4	14.0	12.7	11.5	11.1

Contributor: Boyd, E.

Reference: Engel, S., Arch. Kinderh. 60:267, 1913.

25. DIMENSIONS OF TRACHEA: MAN

Based on data of Engel, Gegovd, Koike, Mettenheimer, Oppikofer, Passavant, and Scammon.

	Age	Length		Lumen Diameter		
		Specimens no.	cm	Specimens no.	Sagittal mm	Frontal mm
	(A)	(B)	(C)	(D)	(E)	(F)
1	0-1 mo	20	4.0	11	3.6	5.0
2	1-3 mo	30	3.8	35	4.6	6.1
3	3-6 mo	35	4.2	37	5.0	5.8
4	6-12 mo	23	4.3	25	5.6	6.2
5	1-2 yr	17	4.5	18	6.5	7.6
6	2-3 yr	19	5.0	22	7.0	8.8
7	3-4 yr	12	5.3	12	8.3	9.4
8	4-6 yr	22	5.4	25	8.0	9.2
9	6-8 yr	14	5.7	16	9.2	10.0
10	8-10 yr	14	6.3	16	9.0	10.1
11	10-12 yr	8	6.3	10	9.8	11.3
12	12-14 yr	5	6.4	6	10.3	11.1
13	14-16 yr	9	7.2	10	12.7	14.0
14	Adult		12(9-15)		17.2(13-23)	14.7(12-18)

Contributor: Boyd, E.

Reference: Scammon, R. E., in "Pediatrics" (Abt, I. A., ed.), vol 1, p 257, Philadelphia: W. B. Saunders Co., 1923.

26. DIAMETER OF SINUSES: MAN

Values are in millimeters.

	Age	No.	Diameter			
			Ostium	Vertical	Lateral	Ant.-Post.
	(A)	(B)	(C)	(D)	(E)	(F)
	Left Frontal					
1	8 da-1 yr	10	2.5 x 0.75	2.7	1.6	3.3
2	1-2 yr	10	2.3 x 0.75	4.0	2.5	3.8
3	2-3 yr	8	2.0 x 0.87	6.5	3.1	5.4
4	5-6 yr	3	3.5 x 1.8	9.0	5.1	7.0
5	9-10 yr	2	3.5 x 2.0	8.5	6.2	7.5
6	13-14 yr	3	4.1 x 1.7	11.3	11.8	12.3
7	17-18 yr	4	2.8 x 1.4	26.2	26.5	10.6
8	20-21 yr	2	5.0 x 3.1	26.6	19.0	18.2
	Left Sphenoidal					
9	8 da-1 yr	10	0.7 x 0.7	2.8	2.0	1.6
10	1-2 yr	10	0.9 x 0.7	4.5	3.4	2.2
11	2-3 yr	8	1.0 x 0.7	5.4	4.1	2.8
12	5-6 yr	3	1.6 x 1.3	7.0	5.4	5.0
13	9-10 yr	2	3.2 x 2.0	11.0	12.2	7.3
14	13-14 yr	3	3.0 x 1.3	10.8	11.1	11.7
15	17-18 yr	4	3.0 x 1.0	21.0	15.3	20.2
16	20-21 yr	2	2.5 x 0.9	22.0	15.3	18.0
	Left Maxillary					
17	8 da-1 yr	10	1.5 x 0.6	5.7	4.6	13.3
18	1-2 yr	10	2.1 x 0.8	8.3	6.7	17.9
19	2-3 yr	8	2.0 x 0.8	9.2	7.9	20.2
20	5-6 yr	3	3.3 x 1.1	12.3	14.0	26.2
21	9-10 yr	2	4.0 x 2.5	18.5	19.0	30.5
22	13-14 yr	3	3.7 x 1.1	23.6	18.0	31.1
23	17-18 yr	4	3.3 x 1.5	32.2	24.5	36.0
24	20-21 yr	2	3.5 x 1.0	26.5	20.0	32.0

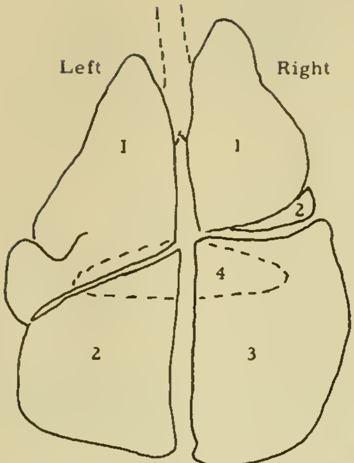
Contributor: Boyd, E.

Reference: Davis, W. B., "Development and Anatomy of the Nasal Accessory Sinuses in Man," Philadelphia: W. B. Saunders Co., 1914.

27. LUNG WEIGHT RELATIONSHIPS: LABORATORY MAMMALS

Part I: LUNG LOBES

Lobes arbitrarily numbered as referred to in Part III.



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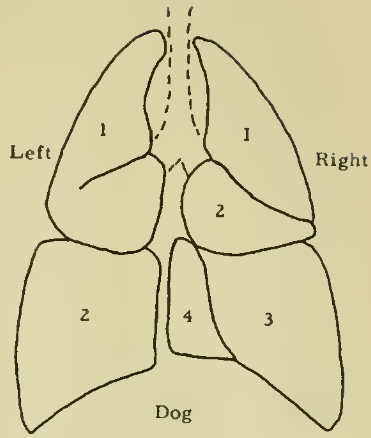
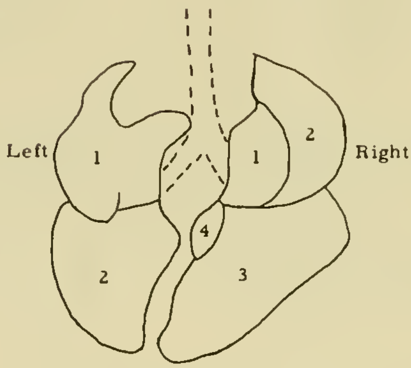


Dog

<u>Left</u>

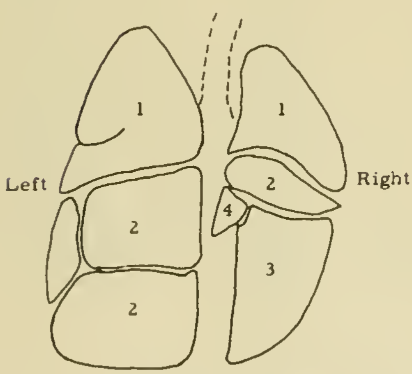
1 = Apical (superior)
2 = Diaphragmatic (inferior)



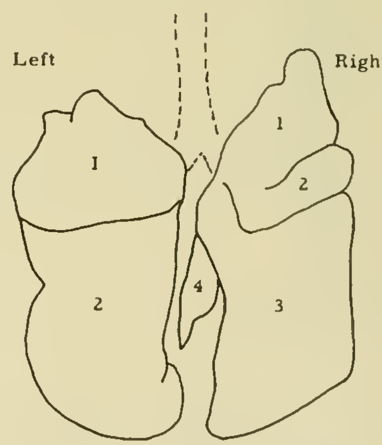
Guinea pig

<u>Right</u>

1 = Apical (superior)
2 = Middle
3 = Diaphragmatic (inferior)
4 = Azygos (mediastinal)



Monkey



Rabbit

Contributors: (a) Joffe, M. H., (b) Ross, B. B.

References: [1] U. S. Army Chemical Warfare Laboratories, Army Chemical Center, Maryland. [2] Rahn, H., and Ross, B. B., J. Appl. Physiol. 10:154, 1957.

27. LUNG WEIGHT RELATIONSHIPS: LABORATORY MAMMALS (Concluded)

Part II: BODY WEIGHT VS LUNG WEIGHT

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Animal	No.	Body Weight kg	Wet Weight: Whole Lung g	Wet Weight: % Body Weight	Dry Weight: Whole Lung g	Dry Weight: % Body Weight	Dry Weight: % Wet Weight	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Cat	5	3.08(2.1-4.0)	23.19(16.3-28.0)	0.75	5.57(3.6-6.8)	0.18	24.43	1
2	Dog	11	18.3(11.5-25.0)			42.6(25.2-68.9)	0.23		2
3	Guinea pig	16	0.50(0.29-0.76)	4.11(2.3-7.0)	0.82	0.86	0.17	20.86	1
4	Monkey	6	3.12(2.1-4.1)	25.46(20.0-33.0)	0.82	5.52(3.9-8.1)	0.18	21.66	1
5	Rabbit	4	2.33(2.0-2.5)	10.5(9.8-13.0)	0.45	2.23(2.0-2.6)	0.10	21.55	1

Contributors: (a) Joffe, M. H., (b) Ross, B. B.

References: [1] U. S. Army Chemical Warfare Laboratories, Army Chemical Center, Maryland. [2] Ross, B. B., unpublished.

Part III: LUNG LOBE WEIGHT RELATIONSHIPS

Specification: A-W = actual weight in grams; % T-D-W = % total dry weight.

	Animal	Specification	Lung Lobe: (Left Apical) L1	Lung Lobe: (Left Diaphragmatic) L2	Lung Lobe: (Right Apical) R1	Lung Lobe: (Right Middle) R2	Lung Lobe: (Right Diaphragmatic) R3	Lung Lobe: (Azygos) R4	Trachea[1]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Cat	A-W	0.77	1.2	0.70	0.38	1.23	0.37	0.96	1
2		% T-D-W	13.38	21.55	12.6	6.66	22.0	6.68	17.2	
3	Dog	A-W	5.3	9.2	5.7	3.1	8.8	2.8	7.7	2
4		% T-D-W	12.4	21.6	13.4	7.3	20.7	6.6	18.1	
5	Monkey	A-W	1.07	1.31	0.70	0.43	1.44	0.24	0.38	1
6		% T-D-W	19.3	23.73	12.7	7.8	26.08	4.36	6.86	
7	Rabbit	A-W	0.21	0.61	0.20	0.20	0.63	0.11	0.29	1
8		% T-D-W	9.14	26.74	8.72	8.85	27.84	4.89	12.6	

/1/ Tracheal length weighed included structure between thyroid cartilage and bifurcation.

Contributors: (a) Joffe, M. H., (b) Ross, B. B.

References: [1] U. S. Army Chemical Warfare Laboratories, Army Chemical Center, Maryland. [2] Ross, B. B., unpublished.

28. LUNG WEIGHT: VERTEBRATES

Part I: MAMMALS

Values, unless otherwise indicated, are for adult weights, on a fresh basis, and are g/100g body weight determined immediately after death of animal.

	Species	No. and Sex	Body Weight kg	Lung Weight g	Lung Weight g/100g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
	Primates					
1	Man, Maya Quiche Indian, 25 yr	1♂	42	1315	3.13	Guatemala
2	35 yr	1♂	43.4	755	1.74	Guatemala
3	American, white	1♂	63.5	360	0.57	New York
4		1♂	70.3	620	0.88	New York
5	Baboon (Papio cynocephalus)	1♂	19.51	175	0.89	Moto Umba, Africa
6	Chimpanzee (Troglodytes niger)	1♂	52.16	600	1.15	Budonga Forest, Uganda, Africa
7	Monkey, gray (Cercopithecus mitis kibonotensis)	1♀	1.22	9.98	0.82	Maji Moto, Africa
8		2♂	3.73	28.51	0.75	Maji Moto, Africa
9	Howler, black (Alouatta palliata inconsonons)	10, ♂♀	0.67[1]	9.88[1]	1.47[1]	Panama
10		3, ♂♀	2.68[2]	22.7[2]	0.85[2]	Panama
11		28, ♂♀	6.17	38.68	0.627	Panama
12	Howler, brown (A. palliata palliata)	5, ♂♀	1.21[2]	11.5[2]	0.95[2]	Panama
13		6, ♂♀	3.12	28.3	0.91	Panama
14	Humboldt (Lagothrix humboldti)	1♀	5.26	63.5	1.21	South America
15	Lemur (Galago senegalensis)	1♀	0.20	1.44	0.72	Maji Moto, Africa
16	Ring-tailed (Lemur catta)	1♀	1.73	24.7	1.43	Zoo
17	Macaque, rhesus (Macaca rhesus)	1♀	1.39[2]	6.2[2]	0.45[2]	Ohio
18		7♀	3.63	68.5	1.89	Laboratory
19	Night (Aotus zonalis)	18, ♂♀	1.93[2]	17.3[2]	0.90[2]	Panama
20	Spider, red (Ateles geoffroyi)	19, ♂♀	1.03[2]	11.98[2]	1.16[2]	Panama
21		63, ♂♀	7.63	51.38	0.67	Panama
22	Spider, black (A. dariensis)	18, ♂♀	1.93[2]	17.30[2]	0.89[2]	Panama
23	Squirrel (Leontocebus geoffroyi)	133, ♂♀	0.19[1]	3.13[1]	1.64[1]	Panama
24		19, ♂♀	0.475[2]	3.91[2]	0.87[2]	Panama
25		8, ♂♀	0.793	8.48	1.07	Panama
26	Sykes (Cercopithecus sp)	2♂	4.94	21.36	0.43	Maji Moto, Africa
27	Vervet (C. aethiops centralis)	2♂	4.19	17.01	0.406	Maji Moto, Africa
28		1♀	1.23[2]	9.98[2]	0.81[2]	Maji Moto, Africa
29	Whiteface (Cebus capucinus linnaeus)	27, ♂♀	0.59[1]	7.93[1]	1.34[1]	Panama
30		6, ♂♀	1.32[2]	20.44[2]	1.55[2]	Panama
31		14, ♂♀	3.10	34.07	1.1	Panama
32	Yellow titi (Saimiriorstedii orstedii reinhardt)	60, ♂♀	0.607	7.20	1.19	Panama
	Carnivores					
33	Bear, polar (Thalarctos maritimus)	2, ♂♀	258.5	2140	0.83	Zoo
34	Cat, domestic (Felis domesticus)	2, ♂♀	1.54	15	0.97	Panama
35	Genet (Genetta tigrina suahelica)	2♂, 1♀	1.38	17.77	1.28	Maji Moto, Africa
36	Wildcat (Felis ocreata)	1♀	2.70	9.0	0.33	Maji Moto, Africa
37	Cheetah (Acinonyx jubatus)	1♂	40.8	360	0.88	Zoo
38	Coati (Nasua nasua panamaensis)	1♂	6.25	43	0.69	Guatemala
39	Coyote (Canis latrans)	1♀	8.51	61.28	0.72	Kansas
40	Dog (Canis familiaris)	3♂, 2♀	13.70	315	2.3	Maji Moto, Africa
41	Greyhound	1♂	24.49	363.5	1.48	Tennessee
42	Husky	2♂	31.75	431	1.36	Churchill, Canada
43	Mongrel	2♂, 2♀	13	123.2	0.94	Florida and Ohio
44	Collie-police	4♀	23.71	192.7	0.81	Ohio
45	Fox, bat-eared (Otocyon megalotis)	1♀	3.34	35.05	1.05	Maji Moto, Africa
46	Gray (Urocyon cineroargenteus scotti)	1♂	3.76	19.12	0.51	Florida
47	Jakal (Thos mesomelas)	2♂	2.85	30.08	1.05	Lake Manyara, Africa
48	Jaguar (Felis onca)	1♀	34.47	576.0	1.67	Zoo
49	Kinkajou (Potos flavus aztecus)	1♀	2.62	78.5	2.99	Guatemala
50	Leopard (Felis pardus)	1♂	48	500	1.04	Zoo
51	Lion (Felis leo)	3♂, 1♀	128.2	2090	1.63	Zoo
52		2♂	190.9	2300	1.20	Maji Moto, Africa
53	Mountain (F. oregonensis)	1♂	28.79	326	1.13	New Mexico
54	Mongoose (Ichneumia albicauda)	1♂	4.40	58	1.32	Maji Moto, Africa
55	Raccoon (Procyon loter pumilis)	1♂, 2♀	3.99	81.47	2.04	Florida, and zoo

/1/ Infant. /2/ Juvenile.

Part I: MAMMALS (Continued)

Values, unless otherwise indicated, are for adult weights, on a fresh basis, and are g/100g body weight determined immediately after death of animal.

	Species	No. and Sex	Body Weight kg	Lung Weight g	Lung Weight g/100g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
	Carnivores (concluded)					
56	Seal, bearded (Erignathus barbatus)	1♀	281	4536	1.61	Canada
57	(Phoca richardi geronimensis)	1♂	107.3	1880	1.75	California
58	Ringed (P. hispida)	3♂, 2♀	39.73	734	1.85	Canada
59	Serval (Felis capensis)	1♂, 2♀	7.88	87.8	1.11	Maji Moto, Africa
60	Skunk (Mephitis mephitis)	1♂	1.7	27.1	1.59	New York
61	Tiger (Felis tigris)	2, ♂♀	184	1454	0.79	Zoo
62	Weasel, arctic (Mustela arctica)	3♂, 1♀	0.182	3.72	2.04	Canada, and zoo
63	Wolf, Russian (Canis lupus lupus)	1♂	22.68	807	3.56	Zoo
64	Timber (C. lubilus)	1♂	29.94	379	1.26	Minnesota
	Rodents					
65	Agouti, brown (Dasyprocta punctata dariensis)	2, ♂♀	3.17	16	0.50	Panama
66	Spotted (Cuniculus paca virgatus)	3, ♂♀	3.63	23.5	0.65	Panama
67	Beaver (Castor canadensis)	2, ♂♀	5.01	48.9	0.97	Michigan
68	Capybara (Hydrochoerus isthimius)	2, ♂♀	27.67	227	0.82	Panama
69	Chipmunk (Tamias striatus fisheri)	2♂	0.075	0.719	0.96	Cleveland, Ohio
70	Guinea pig (Cavia cutleri)	56♂, 66♀	0.368	3.56	0.97	Cleveland, Ohio
71	Hamster, golden (Cricetus cricetus)	2♂, 2♀	0.118	0.54	0.46	Cleveland, Ohio
72	Hare, African (Lepus capencis)	1♀	2.93	17.91	0.61	Maji Moto, Africa
73	Arctic (L. arcticus arcticus)	2♂, 2♀	2.27	43.9	1.93	Tavane, Canada
74	Lemming, brown (Lemmus trinucronatus)	4♂, 1♀	0.039	0.77	1.97	Churchill, Canada
75	Rock (Dicrostonyn rubricatus richardsoni)	4♂	0.052	0.83	1.59	Churchill, Canada
76	Mouse, African (Mastomys coucha microdon)	1♂	0.022	0.24	1.10	Maji Moto, Africa
77	Dormouse (Claviglis saturatus)	1♂	0.018	0.27	1.50	Maji Moto, Africa
78	Jumping (Zapus hudsonicus)[3]	1♂, 3♀	0.017	0.243	1.42	Ohio
79	Meadow (Microtus drummondi)[3]	67♂, 42♀	0.023	0.39	1.70	Churchill, Canada
80	(M. pennsylvanicus pennsylvanicus)	53♂, 42♀	0.026	0.394	1.51	Ohio
81	(Peromyscus sp)[3]	14♂, 2♀	0.015	0.26	1.71	Guatemala
82	Muskrat (Ondatra zibethica alba)	1♂	0.9	4.35	0.98	Churchill, Canada
83	Porcupine (Erethizon dorsatus)	2, ♂♀	2.91	29	0.98	Maji Moto, Africa, and New York
84	Rabbit, Flemish giant (Lepus sp)	22♀	2.59	13.72	0.53	Ohio
85	Rat, Norway (Rattus norvegicus)	2♂, 1♀	0.251	1.98	0.79	Ohio
86	Squirrel, ground (Citellus paryii paryii)	5♂, 3♀	0.908	10.23	1.11	Churchill, Canada
87	Red (Sciurus hudsonicus)	5♂, 4♀	0.21	2.91	1.38	Churchill, Canada
88	(S. hudsonicus loquax)	2♂, 2♀	0.17	2.29	1.35	Cleveland, Ohio
	Artiodactyles					
89	Bison, American (Bison bison)	1♂	54.9	1190	2.17	California
90	Buffalo (Syncerus caffer caffer)	2♂	759	8110	1.07	Maji Moto, Africa
91	Bushbuck (Tragelaphus scriptus massaicus)	2, ♂♀	44.2	727	1.64	Maji Moto; Lake Manyara, Africa
92	Caribou, Barren ground (Rangifer arcticus arcticus)	2♂, 1♀	112.0	1862	1.66	Canada
93	Cattle, calf (Bos taurus)	1♂	10.89[1]	302[1]	2.77[1]	Kentucky
94		1♀	98.4	1411	1.43	Kentucky
95	Cow, Aberdeen Angus[4]	1♀	719	2654	0.37	Kentucky
96	Ayrshire[4]	44♀	491	3311	0.67	Kentucky
97	Guernsey[4]	62♀	450	3143	0.698	Kentucky
98	Holstein[4]	200♀	574	4336	0.75	Kentucky
99	Jersey[4]	218♀	413	3057	0.74	Kentucky
100	Deer (Odocoileus chiriquensis)	1♀	13.9	520	3.73	Panama
101	Indian axis (Cervas axis)	1♂	88.5	1726	1.95	Zoo
102	White-tailed (Odocoileus virginianus)	1♂	65.2	1318	2.02	Zoo
103	Dik-dik (Rhynchotragus kirki)	1♂	4.97	44.4	0.97	Maji Moto, Africa
104	Elk (Cervus canadensis)	1♂	13.61	319	2.34	Zoo
105	Gazelle, Thomson's (Gazella thomsoni)	2♂	24.37	280	1.15	Maji Moto, Africa
106	Giraffe (Giraffa camelopardalis tippelskischi)	1♂	1220	12,060	0.99	Maji Moto, Africa

/1/ Infant. /3/ Preserved weight. /4/ Data furnished by the Bureau of Animal Industry, U. S. Dept. of Agriculture.

Part I: MAMMALS (Concluded)

Values, unless otherwise indicated, are for adult weights, on a fresh basis, and are g/100g body weight determined immediately after death of animal.

	Species	No. and Sex	Body Weight kg	Lung Weight g	Lung Weight g/100g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
	Artiodactyles (concluded)					
107	Hartebeest, Coke's (Bublis cokei cokei)	1♂	134	1850	1.38	Maji Moto, Africa
108	Hippopotamus (Hippopotamus amphibius)	1♀	543[3]	4910[3]	0.903[3]	Maji Moto, Africa
109		1♀	1351	11,340	0.84	Maji Moto, Africa
110	Impala (Acpyceros melampus)	4♂	47.73	650	1.36	Maji Moto, Africa
111	Lamb (Ovis aries)	4♂, 7♀	33.9	624.1	1.84	Kentucky
112	Peccary, collared (Pecari angulatus bangsi)	1♂	29	279	0.96	Zoo
113	Reedbuck (Redunca redunca tohi)	2♂	31.7	462	1.47	Lake Manyara, Africa
114	Steinbok (Raphicerus campestris neumanni)	2♂	8.62	150	1.74	Maji Moto, Africa
115	Swine (Sus scrofax)	2♂, 1♀	8.98	255.2	2.84	Kentucky
116		1♀	113.2	609.7	0.538	Kentucky
117	Warthog (Phacochoerus acthiopicus)	1♂	65.3	550	0.84	Maji Moto, Africa
118	Wildbeast (Gnutaurinus albojubatus)	2♂	212	2850	1.34	Maji Moto, Africa
	Perissodactyles					
119	Burro (Equus asinus)	1♀	150.7	1260	0.83	Guatamala
	Horse (Equus caballus)					
120	Arabian stallion, 28 yr[5]	2♂	412	5777	1.40	Ohio
121	Percheron, 18 yr[5]	2, ♂♀	703	5510	0.78	Ohio
122	Polo pony, 25 yr[5]	1♀	380	8616	1.50	Ohio
123	Saddle-bred gelding	2♂	335[2]	3189[2]	0.95[2]	Kentucky
124	Shetland pony	1♂	272	1871	0.69	Ohio
125	Thoroughbred, 2-3 yr[5]	3♂, 7♀	421.2	4123	0.98	Kentucky
126	Colt, yearling	9♂, 1♀	319	3043	0.95	Kentucky
127	Foal, 4.3 da[5]	18♂, 19♀	53.38	1390	2.60	Kentucky
128	Fetus, 15.3 da premature[5]	15♂, 11♀	43.29	1352	3.12	Kentucky
129	50.4 da premature[5]	5♂, 5♀	26.88	1135	4.22	Kentucky
130	Stallion, 15.1 yr[5]	6♂	508	5977	1.17	Kentucky
131	Mule, Panama (Equus asinus)	4, ♂♀	279.2	4026	1.44	Panama
132		1♂	42.64[2]	628[2]	1.47[2]	Panama
133		1♀	444.5	5678	1.28	Kentucky
134	Rhinoceros (Rhinoceros bicornis)	1♂	764	7350	0.96	Maji Moto, Africa
135	Tapir (Tapirella bairdii)	1♀	58.1	2068	3.55	Panama Canal Zone
136	Zebra (Equus quagga granti), embryo	1♂	7.9	300	3.79	Maji Moto, Africa
137	Fetus	1♂	29.5	655	2.22	Zoo
138	Infant	1♀	43.1	740	1.72	Zoo
139	6 wk	1♀	56.6	1025	1.81	Maji Moto, Africa
140	Adult	2♂	255	2025	0.79	Maji Moto, Africa
	Proboscideans, Hyracoideans, and Sirenians					
141	Elephant (Loxodonta africana knochenhaueri)	1♂	6654	138,790	2.08	Maji Moto, Africa
142	Hyrax (Heterohyrax brucci)	1♂	0.75	5.53	0.74	Lake Manyara, Africa
143	Manatee (Trichechus manatus)	2, ♂♀	496	3395	0.68	Florida
	Cetaceans					
144	Porpoise (Phocaena phocaena)	1♂	142.4	5250	3.69	Florida
145	Whale, white (Delphinapterus leucas)	4♂, 2♀	375.1	10,014	2.67	Churchill, Canada
	Insectivores					
146	Mole (Scalopus aquaticus)	1♂	0.04	0.74	1.86	Ohio
147	Shrew (Blarina breuicauda)	29♂, 39♀	0.018	0.39	2.16	Ohio
	Edentates					
148	Anteater (Tamanduas tetractyla chiriquensis)	2, ♂♀	3.69	27	0.73	Panama
149	Armadillo (Dasypusnovemcinctus fenestratus)	10, ♂♀	3.4	24	0.70	Panama
150	Sloth, three-toed (Bradypus griseus griseus)	4, ♂♀	2.0[2]	27.4[2]	1.37[2]	Panama
	Marsupials					
151	Opossum (Didelphis marsupialis etensis)	4, ♂♀	1.15	9.5	0.83	Panama

/2/ Juvenile. /3/ Preserved weight. /5/ Average.

Contributor: Quiring, D. P.

Reference: Quiring, D. P., "Functional Anatomy of the Vertebrates," New York: McGraw Hill, 1950.

Part II: BIRDS

Values, unless otherwise indicated, are for adult weight, on a fresh basis, and are g/100g body weight determined immediately after death of animal.

	Species	No. and Sex	Body Weight kg	Lung Weight g	Lung Weight g/100g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
1	Blackbird (Quiscalus quiscula aeneus)	1♂	0.082	0.172	0.21	Ohio
2	Bustard, greater (Choriotis kori, struthiunculus)	2, ♂♀	7.77	85.24	1.09	Athi Plain, Africa
3	Lesser, (Haliaoetus bociter bociter)	1♀	1.10	14.4	1.30	Maji Moto, Africa
4	Buzzard, steppe (Buteo vulpinus vulpinus)	1♂	0.56	4.64	0.83	Maji Moto, Africa
5	Turkey (Cathartes aura septentrionalis)	1♂	0.5	14.7	2.94	Florida
6	Catbird (Dumetella carolinensis)	1♀	0.033	0.607	1.84	Ohio
7	Canary (Serinus canarius)	1♂	0.017	0.25	1.47	Ohio
8	Crane, crested (Balearica pavonina)	2, ♂♀	4.45	44.13	0.99	Ohio
9	Gray (Grus canadensis)	1♂	1.65	15.33	0.93	Florida
10	Crow (Corvus brachyrhynchos)	1♂	0.34	9.97	2.93	Ohio
11	Dovekie (Alle alle)	2, ♂♀	0.103	1.65	1.61	Florida
12	Duck (Nyroca affinis)	1♂	1.041	17.6	1.69	Ohio
13	Pintail (Dafila acuta tzitzihoa)	1♀	0.67	17.1	2.56	Churchill, Canada
14	Eagle, fish (Haliaetus vocifer vocifer)	1♀	3.5	47.33	1.35	Maji Moto, Africa
15	Tawney (Aquila rapax rapax)	3♂	2.05	25.1	1.22	Maji Moto, Africa
16	Egret, great white (Casmerodius albus melanorhynechos)	1♀	1.03	33.10	3.21	Maji Moto, Africa
17	Yellow-bill (Mesophyox intermedia brachyrhyneha)	1♂	0.525	5.4	1.02	Maji Moto, Africa
18	Flamingo (Phoeniconaias minor)	2♂, 3♀	1.504	22.33	1.48	Maji Moto, Africa
19	Fowl, leghorn (Gallus gallus domesticus)	4♀	1.263	10.5	0.87	Ohio
20	108 da old	10♂, 10♀	0.49	4.13	0.84	Ohio
21	136 da old	8♂, 16♀	0.674	4.1	0.6	Ohio
22	White Orpington	1♂	2.2	13.17	0.59	Ohio
23	White Wyandotte bantam, conventional[1]	2♂, 5♀	0.72	3.09	0.43	Ohio
24	Germfree[1]	3♂, 2♀	0.83	2.49	0.30	Ohio
25	Goose, Egyptian (Alopochen aegypticus)	1♀	1.94	35.2	1.80	Lake Manyara, Africa
26	Guinea fowl (Numida meleagris)	1♂	1.62	29.0	1.79	Maji Moto, Africa
27	Gull, Bonaparte's (Larus philadelphia)	1♂	0.2	7.12	3.56	Churchill, Canada
28	Ring-billed (L. delawarensis)	1♀	0.72	9.13	1.27	Florida
29	Shearwater (Puffinus griseus)	1♀	0.27	2.45	0.91	Florida
30	Hawk, red-tailed (Buteo borealis)[2]	1♀	1.03	9.3	0.9	Ohio
31	Sharp-shinned (Accipiter velox velox)	1♀	0.52	7.7	1.48	Ohio
32	Sparrow (Falce sparverius sparverius)	1♂	0.112	1.5	1.36	Florida
33	Hornbill, ground (Bucorvus cafer)	1♂	3.3	52.3	1.61	Maji Moto, Africa
34	Hummingbird (Amazilia tzacatl tzacatl)	1♀	0.005	0.095	1.9	Guatemala
35	Loon, red-throated (Gavia stellata)	2♂, 1♀	1.56	22.5	1.44	Tavane, Canada
36	Merganser, red-breasted (Mergus serrator)	1♀	0.8	18.2	2.27	Tavane, Canada
37	Ostrich, Masai (Struthio camelus massaicus)	1♂	123	2900	2.36	Maji Moto, Africa
38	Owl, horned (Bubo virginianus virginianus)	1♂	1.18	10.7	0.91	Ohio
39	Pelican (Pelecanus occidentalis)	2♀	3.3	29.8	0.91	Florida
40	Pigeon (Columbia livia)	3♂, 1♀	0.26	4.58	1.76	Ohio
41	Ptarmigan, willow (Lagopus lagopus)	3♂, 1♀	0.54	10.17	1.88	Churchill, Canada
42	Robin (Turdus migratorius migratorius)	2♂	0.07	1.68	2.24	Ohio
43	Scaup, greater (Nyroca marila)	1♀	0.79	18	2.29	Churchill, Canada
44	Sparrow (Passer domesticus)	75♂, 11♀	0.0234	0.3837	1.64	Ohio
45	Starling (Sturnus vulgaris)	15♂, 10♀	0.0576	1.08	1.87	Ohio
46	Stork, Abdim (Sphenorhynchus abdini)	1♂	0.95	10.63	1.11	Maji Moto, Africa
47	European (Ciconia ciconia ciconia)	1♂	3.35	27.2	0.81	Maji Moto, Africa
48		2♀	3.35	42.3	1.26	Maji Moto, Africa
49	Hammerhead (Scops umbretta)	1♂	0.32	8.2	2.57	Maji Moto, Africa
50	Marabou (Leptopilos crumeniferous)	2♂	7.13	72.2	1.01	Maji Moto, Africa
51	Teal, green-winged (Nettion carolinensis)	1♀	0.3	9.2	3.07	Churchill, Canada

/1/ For a discussion of the meaning of "germ-free," consult Reference [2]. /2/ Juvenile.

Contributors: (a) Quiring, D. P., (b) Reyniers, J. A., and Gordon, H. A.

References: [1] Quiring, D. P., "Functional Anatomy of the Vertebrates," New York: McGraw Hill, 1950.
[2] Reyniers, J. A., and Gordon, H. A., Lobund Report No. 3, University of Notre Dame.

Part III: REPTILES

Values, unless otherwise indicated, are for adult weights, on a fresh basis, and are g/100g body weight determined immediately after death of animal.

	Species	No. and Sex	Body Weight kg	Lung Weight g	Lung Weight g/100g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
1	Alligator (Alligator mississippiensis)	1♀	52.4	393	0.75	Zoo
2		2♂	189	1014	0.54	Florida
3	Crocodile (Crocodilus americanus)	1♂	134	1.125	0.85	Florida
4	Gila monster (Heloderma suspectum)	1♀	0.514	6.45	1.25	Arizona
5	Lizard, iguana (Iguana iguana)	1♀	1.34	3.70	0.276	Guatemala
6	(Amblyrhynchus cristatus)	1♀	4.19/1/	64.4/1/	1.536/1/	Galapagos Islands
7	Snake, black (Coluber constrictor)	2,♂♀	0.401	3.79	0.88	Ohio
8	Boa, imperator (Boa imperator)	1♀	1.829	14.0	0.76	Guatemala
9	Water moccasin (Agkistrodon piscivorus)	1♀	0.728	22.62	3.12	Florida
10	Turtle (Aromochelys tristycha)	1♂	0.116	0.863	0.741	
11		2♀	0.088	0.954	1.08	
12	(Clemmys guttata)	1♂	2.163	31.95	1.48	Ohio
13	(Chelydra serpentina)	1♀	5.125	85.07	1.66	Maji Moto, Africa
14	(Malacoclymmys lesueri)	1♂	0.254	1.14	0.449	
15	Green (Chelonia mydra)	1♂	111.30	2.650	2.38	Florida
16	Cumberland (Chrysemys elegans)	21♂, 1♀	0.852	0.956	0.112	
17	Snapping (Macrochelys lacertina)	1♂	1.848	34.9	1.89	Ohio

/1/ Preserved weight.

Contributors: (a) Quiring, D. P., (b) Latimer, H. B.

References: [1] Quiring, D. P., "Functional Anatomy of the Vertebrates," New York: McGraw Hill, 1950. [2] Latimer, H. B., Anat. Record 18:35, 1920. [3] Latimer, H. B., ibid 19:347, 1920.

Part IV: AMPHIBIANS

Values, unless otherwise indicated, are for adult weights, on a fresh basis, and are g/100g body weight determined immediately after death of animal.

	Species	No. and Sex	Body Weight kg	Lung Weight g	Lung Weight g/100g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
1	Frog, bullfrog (Rana catesbiana)	7♂	0.429	2.27	0.53	La., N. Carolina
2	Leopard (R. pipiens)	10♂, 19♀	0.037	0.81	2.19	
3		20♂, 10♀	0.0275/1/	0.86/1/	3.128/1/	
4	Toad, horned (Phrynosoma cornutum)	2♂, 3♀	0.025	0.594	2.48	Arizona

/1/ Preserved weight.

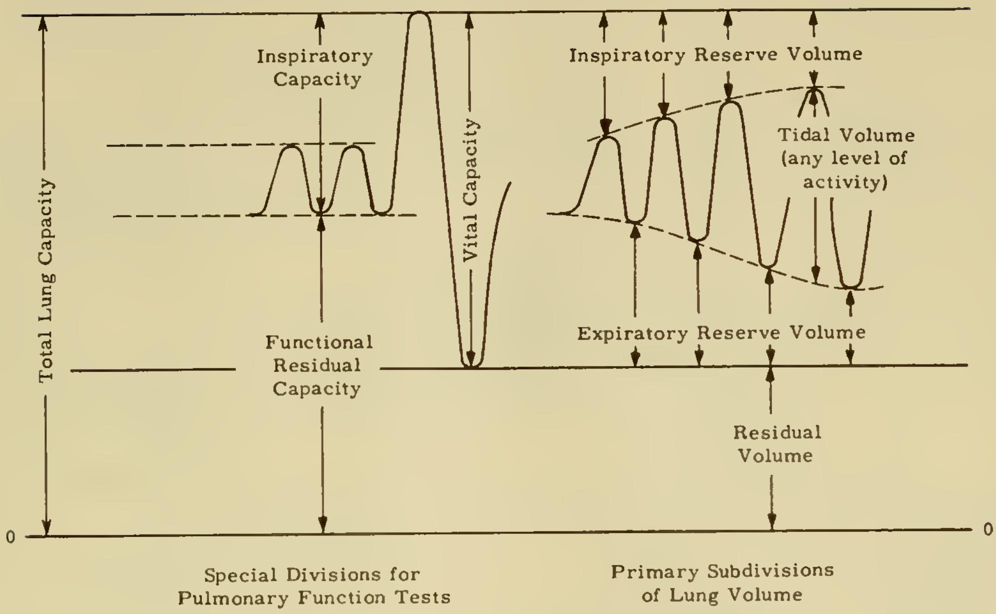
Contributors: (a) Quiring, D. P., (b) Latimer, H. B.

References: [1] Quiring, D. P., "Functional Anatomy of the Vertebrates," New York: McGraw Hill, 1950. [2] Latimer, H. B., Anat. Record 18:35, 1920. [3] Latimer, H. B., ibid 19:347, 1920.

29. SUBDIVISIONS OF LUNG VOLUME: MAN

Part I: DIAGRAM

Volumes corrected to BTPS conditions (cf Page 1).



Reference: Comroe, J. H., Jr., et al, Fed. Proc. 9:602, 1950.

Part II: STANDARDIZED TERMS VS SOME PREVIOUS TERMS

	Standardized Term	Definition	Previous Term
1	Inspiratory reserve volume	Maximal volume that can be inspired from end-tidal inspiration.	Complemental air. Complementary air. Complemental air minus tidal air. Inspiratory capacity minus tidal volume.
2	Tidal volume	Volume of gas inspired or expired during each respiratory cycle.	Tidal air.
3	Expiratory reserve volume	Maximal volume that can be expired from resting expiratory level.	Supplemental air. Reserve air.
4	Residual volume	Volume of gas in lungs at end of maximal expiration.	Residual air. Residual capacity.
5	Inspiratory capacity	Maximal volume that can be inspired from resting expiratory level.	Complemental air. Complementary air.
6	Functional residual capacity	Volume of gas in lungs at resting expiratory level.	Functional residual air. Equilibrium capacity. Mid-capacity. Normal capacity.
7	Vital capacity	Maximal volume that can be expired after maximal inspiration.	Vital capacity.
8	Total lung capacity	Volume of gas in lungs at end of maximal inspiration.	Total lung volume.

Reference: Comroe, J. H., Jr., "The Lung," Chicago: The Year Book Publishers, 1956.

Part I: LUNG VOLUMES

A = adults; C = children; BSA = body surface area. Age is in years.

	Measurement (A)	Subject (B)	Formula (C)	Value (D)	Reference (E)
1	Vital capacity, L	C ♂		(0.79-3.78)[1,2,3]	1
2		C ♀		(0.66-2.94)[1,2,3]	1
3		A ♂	$[27.63-(0.112 \times \text{age})] \times \text{ht in cm} \times 10^{-3}$	(2.18-5.43)[4,5]	2
4		A ♀	$[21.78-(0.101 \times \text{age})] \times \text{ht in cm} \times 10^{-3}$	(1.57-4.15)[4,5]	2
5	L/sq m BSA	A ♂		2.5[6]	3
6		A ♀		2.0[6]	3
7	Residual volume, ml	C ♂	(11.1 x ht in cm) - 1,055		4
8	L	C ♂		(0.60-1.13)[2,5,7,8]	4
9		C ♂		(0.26-1.75)[2,5,9,10]	5
10	% total lung capacity	A ♂♀		(20-30.8)[2,8]	6
11	Total lung capacity, L	16-34 yr ♂♀	$\frac{\text{Vital capacity}}{80} \times 100$		2
12		35-49 yr ♂♀	$\frac{\text{Vital capacity}}{76.6} \times 100$		2
13		50-69 yr ♂♀	$\frac{\text{Vital capacity}}{69.2} \times 100$		2
14		A ♂		(3.62-7.68)[4,5,8]	6
15		A ♀		(3.20-6.18)[4,5,8]	6
16		A ♂		5.49(2.31-7.24)[4,5,11]	7
17		A ♀		4.32(3.20-5.31)[4,5,11]	7
18	Physiologic dead space, cc	A ♂		156(106-219)	8
19		A ♀		104	8
	Timed vital capacity, % total vital capacity				
20	First sec	A ♂♀		83(72-98)	9, 10
21	First 2 sec	A ♂♀		94(88-100)	9, 10
22	First 3 sec	A ♂♀		97(92-100)	9, 10

/1/ Age range 4-17 yr. /2/ Increases with age. /3/ Volume uncorrected (cf Page 1); body position not stated. /4/ Decreases with age. /5/ Volume corrected to BTPS (cf Page 1); body position supine. /6/ Assuming normal weight range. /7/ Age range 10-17 yr. /8/ Closed-circuit oxygen rebreathing technique. /9/ Age range 6-17 yr. /10/ Closed-circuit hydrogen rebreathing technique. /11/ Closed-circuit helium rebreathing technique.

Contributor: Gaensler, E. A.

References: [1] Stewart, C. A., Am. J. Dis. Child. 24:451, 1922. [2] Baldwin, E. deF., Cournand, A., and Richards, D. W., Jr., Medicine 27:243, 1948. [3] West, H. F., Arch. Int. M. 25:306, 1920. [4] Morse, M., Schlutz, F. W., and Cassels, D. E., J. Clin. Invest. 30:380, 1952. [5] Robinson, S., Arbeitsphysiologie 10:251, 1938. [6] Kaltreider, N. L., Fray, W. W., and Hyde, H. V., Am. Rev. Tuberc. 37:662, 1938. [7] Whitfield, A. G., Waterhouse, J. A., and Arnott, W. M., Brit. J. Social M. 4:1, 1950. [8] Fowler, W. S., Am. J. Physiol. 154:405, 1948. [9] Gaensler, E. A., Am. Rev. Tuberc. 64:256, 1951. [10] Gaensler, E. A., Science 114:444, 1951.

Part II: BASAL RESPIRATORY FUNCTIONS

A = adults; C = children; BSA = body surface area; MBC = maximal breathing capacity.

	Measurement (A)	Subject (B)	Formula (C)	Value (D)	Reference (E)
1	Pulmonary ventilation,	A ♂		3.5(2.6-4.9)[1]	1, 2
2	L/min/sq m BSA	A ♀		3.3(2.5-4.3)[1]	1, 2
3	O_2 consumption,	A ♂		138(107-186)[2]	1, 2
4	cc/min/sq m BSA	A ♀		127(105-150)[2]	1, 2
5	Basal heat production,	AC ♂♀	O_2 consumption x 0.2895[3]		3
6	Cal/hr/sq m BSA	C ♂♀		(40-52)[2,4]	3
7		A ♂		(37-41)[2,4]	3
8		A ♀		(34-38)[2,4]	3
9	Ventilatory equivalent,	AC ♂♀	$\frac{\text{Pulmonary ventilation, L}}{\text{oxygen uptake, cc}} \times 100$		2, 4, 5
10	L/100 cc	A ♂♀		(2.2-2.6)[5,6]	2, 4, 5

/1/ Usually expressed at BTPS (cf Page 1). /2/ Usually expressed at STPD (cf Page 1). /3/ Assuming a non-protein respiratory quotient of 0.82, or 4.825 Cal/L of O_2 consumed. /4/ Decreases with age. /5/ Increases with age. /6/ Decreases during exercise.

Part II: BASAL RESPIRATORY FUNCTIONS (Concluded)

A = adults; C = children; BSA = body surface area; MBC = maximal breathing capacity.

	Measurement (A)	Subject (B)	Formula (C)	Value (D)	Reference (E)
11	O_2 removal, cc/L	AC ♂♀	$\frac{\text{Oxygen uptake, cc/min}}{\text{Pulmonary ventilation, L/min}}$		1,6
12		A ♂		43(34-54)[4,7]	1,6
13		A ♀		45(37-62)[4,7]	1,6
14	Breathing reserve, %	A ♂♀	$\frac{\text{MBC (L/min)} - \text{Pulmonary ventilation (L/min)}}{\text{MBC (L/min)}} \times 100$	(88-95)[4]	1,7
15	Right lung, % total[8]	A ♂♀		(51-63)	8
16	Left lung, % total[8]	A ♂♀		(38-49)	8

/4/ Decreases with age. /7/ Increases during exercise. /8/ Percentages of total function apply to oxygen uptake and ventilation at rest and during exercise, to vital capacity and residual volume.

Contributor: Gaensler, E. A.

References: [1] Baldwin, E. deF., Cournand, A., and Richards, D. W., Jr., Medicine 27:243, 1948. [2] Matheson, H. W., and Gray, J. S., J. Clin. Invest. 29:688, 1950. [3] Aub, J. C., and DuBois, E. F., Arch. Int. M. 19:823, 1917. [4] Anthony, A. J., Deut. Arch. klin. Med. 167:129, 1930. [5] Knipping, H. W., and Moncrieff, A., Quart. J. M. 1:17, 1932. [6] Robinson, S., Arbeitsphysiologie 10:3, 1938. [7] Knipping, H. W., Beitr. Klin. Tuberk. 82:133, 1933. [8] Gaensler, E. A., et al, J. Laborat. Clin. M. 39:417; 40:223, 558, 1952.

Part III: EXERCISE AND MAXIMAL VENTILATION; INTRAPULMONARY MIXING

A = adults; BSA = body surface area. Age is in years.

	Measurement (A)	Subject (B)	Formula (C)	Value (D)	Reference (E)
1	Maximal breathing capacity, L/min[1]	A ♂	[228 -(1.82 x age)] ± 17.6%	147(121-173)[2,3]	1
2		A ♂	[86.5 -(0.522 x age)] x BSA in sq m	(58-169)[3,4]	1
3		A ♀	[71.3 -(0.474 x age)] x BSA in sq m	(47-118)[3,4]	2
4	Standard walking ventilation, L/min sq m BSA[1]	A ♂♀		(9-11)[5]	3
5	Walking dyspnea index, %	A ♂♀	$\frac{\text{Actual walking ventilation, L/min}}{\text{Maximal breathing capacity, L/min}} \times 100$	(8-20)[5,6]	3,4
6	Air velocity index	A ♂♀	$\frac{\text{\% of predicted maximal breathing capacity}}{\text{\% of predicted vital capacity}}$	1.0(0.8-1.2)[3]	5
7	Capacity ratio	A ♂♀	$\frac{\text{Maximal breathing capacity, L/min}}{\text{Vital capacity, L}}$	(28-35)[3]	6,7
8	Intrapulmonary mixing,	A ♂♀		<2.5[7]	8
9	% N_2 in alveolar air	A ♂♀		(0.3-1.5)[7]	9

/1/ Usually expressed at BTPS (cf Page 1). /2/ Obtained by open-circuit technique. /3/ Decreases with age. /4/ Obtained by closed-circuit technique. /5/ Standard walk on level at 180 ft/min, expired air collected from second to fourth minute. /6/ Increases with age. /7/ After O_2 breathing, at rest for 7 minutes.

Contributor: Gaensler, E. A.

References: [1] Wright, G. W., "Methods in Medical Research," 2:212, Chicago: The Year Book Publishers, Inc., 1950. [2] Baldwin, E. deF., Cournand, A., and Richards, D. W., Jr., Medicine 27:243, 1948. [3] Patton, W. E., Watson, T. R., Jr., and Gaensler, E. A., Surg. Gyn. Obst. 95:477, 1952. [4] Warring, F. C., Jr., Am. Rev. Tuberc. 51:432, 1945. [5] Gaensler, E. A., ibid 62:17, 1950. [6] Gaubatz, E., Beitr. Klin. Tuberk. 91:201, 1938. [7] Matheson, H. W., Spies, S. N., Gray, J. S., and Barnum, D. R., J. Clin. Invest. 29:682, 1950. [8] Cournand, A., Baldwin, E. deF., Darling, R. C., and Richards, D. W., Jr., J. Clin. Invest. 20:681, 1941. [9] Gaensler, E. A., Frank, N. R., Patton, W. E., Devney, R. E., and Smith, S. S., unpublished.

31. VITAL CAPACITY VS AGE: CHILDREN AND ADOLESCENTS

Ventilatory values have been corrected to BTPS conditions (cf Page 1). Values in parentheses are ranges. Age ranges conform to estimate "c" of the 95% range (cf Introduction). Vital capacity ranges of Ferris and Shock conform to estimate "b" of the 95% range; those of Morse conform to estimate "c."

	Age yr	Vital Capacity, L[1]		
		Ferris[2]	Morse[3]	Shock
	(A)	(B)	(C)	(D)
		Males		
1	5.0-5.9	1.29(0.83-1.75)	0.54[4]	
2	6.0-6.9	1.65(1.27-2.03)	0.92[4]	
3	7.0-7.9	1.93(1.45-2.41)	1.58(1.17-2.00)	
4	8.0-8.9	2.16(1.34-2.98)	1.38[4]	
5	9.0-9.9	2.17(1.69-2.65)	2.13(1.83-2.22)	
6	10.0-10.9	2.30)1.75-2.71)	2.28(1.86-2.53)	
7	11.0-11.9	2.54(1.80-3.28)	2.30(1.86-2.70)	
8	12.0-12.9	3.75(3.21-4.29)	2.65(1.81-3.40)	2.69(1.70-3.48)
9	13.0-13.9	3.81(2.53-5.09)	2.73(1.66-4.33)	3.03(2.13-4.15)
10	14.0-14.9	4.29(2.77-5.81)	3.45(2.06-5.09)	3.43(2.11-4.82)
11	15.0-15.9	4.47(3.23-5.71)	3.84(2.36-5.42)	3.89(2.38-5.33)
12	16.0-16.9	4.51(3.67-5.35)	4.23(3.10-5.55)	4.37(2.93-5.67)
13	17.0-17.9	4.49(3.67-5.31)	3.81(3.55-4.07)	4.61(3.28-6.10)
14	18.0-18.5			4.63(2.92-6.34)
		Females		
15	5.0-5.9	1.08(0.74-1.42)	0.90[4]	
16	6.0-6.9	1.45(1.07-1.83)	1.38(1.13-1.56)	
17	7.0-7.9	1.51(1.19-1.83)	1.56(1.31-1.81)	
18	8.0-8.9	1.87(1.23-2.51)	1.51(1.17-1.90)	
19	9.0-9.9	2.04(1.38-2.70)	1.91(1.70-2.30)	
20	10.0-10.9	2.29(1.81-2.77)	2.40(2.16-2.78)	
21	11.0-11.9	2.57(1.71-3.43)	2.13(1.63-2.67)	
22	12.0-12.9	3.03(2.17-3.89)	2.58(1.83-3.10)	2.58(1.84-3.42)
23	13.0-13.9	3.49(2.13-4.85)	3.00(2.29-4.06)	2.96(2.26-3.71)
24	14.0-14.9	3.40(2.42-4.38)	3.05(2.66-3.59)	3.10(2.42-3.72)
25	15.0-15.9	3.66(2.83-4.44)	3.02(2.50-3.26)	3.16(2.59-3.84)
26	16.0-16.9	3.63(2.91-4.35)	2.66[4]	3.26(2.63-3.99)
27	17.0-17.9	4.00(3.16-4.84)		3.27(2.64-3.96)

/1/ Maximal volume of gas expelled from the lungs by forceful effort, following a maximal inspiration. /2/ Subjects seated; body surface area obtained from DuBois nomogram; Benedict-Roth type spirometer (Collins ventilometer). /3/ All measurements made in recumbent position; Sanborn closed-circuit wet spirometer. /4/ From single determination.

Contributors: (a) Ferris, B. G., Jr., (b) Morrow, P. E., (c) Morse, M., (d) Shock, N. W., (e) Whittenberger, J. L.

References: [1] Ferris, B. G., Jr., Whittenberger, J. L., and Gallagher, J. R., Pediatrics, Springf. 9:659, 1952. [2] Ferris, B. G., Jr., and Smith, C. W., ibid 12:341, 1953. [3] Morse, M., Schlutz, F. W., and Cassels, D. E., J. Clin. Invest. 31:380, 1952. [4] Morse, M., Univ. of Chicago, unpublished. [5] Shock, N. W., and Norris, A. H., Gerontology Branch, National Institutes of Health, unpublished.

Ventilatory values of Stewart conform to ATPS conditions. All other ventilatory values are corrected to BTPS conditions (cf Page 1). Values in parentheses are ranges; in data of Morse they conform to estimate "c" of the 95% range (cf Introduction); in data of Ferris, Shock, and Stewart, they conform to estimate "b," unless otherwise indicated.

	Height cm	Vital Capacity, L[1]			
		Ferris[2]	Morse[3]	Shock	Stewart[4]
	(A)	(B)	(C)	(D)	(E)
			Males		
1	100.0-104.9		0.54[5]		0.79(0.50-0.90)[c]
2	105.0-109.9				1.06(0.79-1.34)
3	110.0-114.9	1.46(0.82-2.10)	0.92[5]		1.19(0.90-1.49)
4	115.0-119.9	1.46(0.82-2.10)			1.34(1.04-1.64)
5	120.0-124.9	1.64(1.32-1.96)	1.27(1.17-1.38)		1.50(1.1 -1.85)
6	125.0-129.9	1.79(1.43-2.15)	1.83[5]		1.67(1.29-2.06)
7	130.0-134.9	2.05(1.63-2.47)			1.85(1.49-2.22)
8	135.0-139.9	2.27(1.37-3.17)	1.99(1.81-2.11)		2.03(1.58-2.48)
9	140.0-144.9	2.41(1.59-3.23)	2.22(1.66-2.58)	2.32(1.92-2.72)	2.22(1.72-2.72)
10	145.0-149.9	2.38(1.76-3.00)	2.40(1.86-3.39)	2.53(2.20-2.86)	2.42(1.88-2.97)
11	150.0-154.9	2.69(1.79-3.59)	2.57(1.89-3.17)	2.80(2.10-3.50)	2.66(2.14-3.18)
12	155.0-159.9	3.52(2.64-4.40)	2.82(2.15-3.40)	2.95(2.40-3.50)	2.93(2.23-3.63)
13	160.0-164.9	3.72(2.78-4.66)	3.22(2.49-3.67)	3.22(2.53-3.91)	3.24(2.51-3.97)
14	165.0-169.9	4.07(3.19-4.95)	3.65(3.00-4.07)	3.54(2.81-4.27)	3.55(2.74-4.36)
15	170.0-174.9	4.47(3.39-5.55)	3.97(3.45-4.72)	3.85(3.11-4.59)	3.99(2.75-4.40)[c]
16	175.0-179.9	4.82(3.74-5.90)	4.30(3.80-4.76)	4.25(3.45-5.05)	4.02
17	180.0-184.9	5.24(4.26-6.22)	5.07(4.74-5.42)	4.72(3.62-5.82)	4.17
18	185.0-189.9			4.99(4.19-5.79)	
19	190.0-194.9			5.77(5.57-5.96)[c]	
			Females		
20	100.0-104.9	0.95(0.40-1.45)			0.88
21	105.0-109.9	1.00(0.80-1.20)			0.85(0.60-1.20)
22	110.0-114.9	1.12(0.78-1.46)			1.14(0.85-1.42)
23	115.0-119.9	1.37(0.99-1.75)	1.01(0.89-1.13)		1.28(0.98-1.58)
24	120.0-124.9	1.70(1.00-2.40)	1.43[5]		1.41(1.13-1.70)
25	125.0-129.9	1.70(1.26-2.14)	1.44(1.31-1.81)		1.56(1.22-1.90)
26	130.0-134.9	1.97(1.31-2.63)	2.01(1.95-2.06)		1.71(1.34-2.07)
27	135.0-139.9	2.19(1.66-2.72)	1.84(1.65-2.14)	2.26(2.15-2.36)[c]	1.87(1.47-2.26)
28	140.0-144.9	2.32(1.68-2.96)	1.84(1.63-2.30)	2.24(2.05-2.42)[c]	2.04(1.59-2.49)
29	145.0-149.9	2.53(1.87-3.19)	2.37(2.16-2.78)	2.47(1.97-2.97)	2.23(1.73-2.73)
30	150.0-154.9	2.94(2.34-3.54)	2.37(2.16-2.67)	2.77(2.15-3.39)	2.44(1.83-3.05)
31	155.0-159.9	3.28(2.44-4.12)	2.70(2.22-3.04)	2.81(2.29-3.33)	2.65(2.00-3.29)
32	160.0-164.9	3.57(2.75-4.39)	3.12(2.60-4.06)	2.98(2.41-3.55)	2.83(2.18-3.48)
33	165.0-169.9	3.85(2.97-4.73)	2.99(2.66-3.59)	3.24(2.45-4.03)	2.98
34	170.0-174.9	3.91(2.39-4.43)	3.23(2.72-3.72)	3.22(2.84-3.60)	3.10
35	175.0-179.9			3.50(2.95-4.05)	

/1/ The maximal volume of gas expelled from the lungs by forceful effort, following maximal inspiration. /2/ Subjects seated; Benedict-Roth type spirometer (Collins ventilometer), with soda lime container and valves removed. /3/ All measurements made in recumbent position; Sanborn closed-circuit wet spirometer. /4/ Position not stated; wet spirometer. /5/ From single determination.

Contributors: (a) Ferris, B. G., Jr., (b) Morrow, P. E., (c) Morse, M., (d) Shock, N. W., (e) Whittenberger, J. L.

References: [1] Ferris, B. G., Jr., Whittenberger, J. L., and Gallagher, J. R., Pediatrics, Springf. 9:659, 1952. [2] Ferris, B. G., Jr., and Smith, C. W., ibid 12:341, 1953. [3] Morse, M., Schlutz, F. W., and Cassels, D. E., J. Clin. Invest. 31:380, 1952. [4] Morse, M., Univ. of Chicago, unpublished. [5] Shock, N. W., and Norris, A. H., Gerontology Branch, National Institutes of Health, unpublished. [6] Stewart, C. A., Am. J. Dis. Child. 24:451, 1922.

Ventilatory values of Stewart conform to ATPS conditions. All other ventilatory values are corrected to BTPS conditions (cf Page 1). Values in parentheses are ranges; in data of Morse they conform to estimate "c" of the 95% range (cf Introduction); in data of Ferris, Shock, and Stewart, they conform to estimate "b," unless otherwise indicated.

	Weight kg	Vital Capacity[1]			
		Ferris[2]	Morse[3]	Shock	Stewart[4]
	(A)	(B)	(C)	(D)	(E)
	Males				
1	15.0-19.9		0.73(0.54-0.92)		(0.99-1.20)
2	20.0-24.9	1.53(0.89-2.17)	1.27(1.17-1.38)		(1.32-1.46)
3	25.0-29.9	1.72(1.28-2.16)	2.05(1.83-2.45)		(1.61-1.77)
4	30.0-34.9	2.10(1.70-2.50)	2.27(1.81-2.58)	2.24(1.94-2.54)	(1.91-2.05)
5	35.0-39.9	2.31(1.45-3.17)	2.44(1.66-3.04)	2.60(2.29-2.91)	(2.18-2.31)
6	40.0-44.9	2.66(1.92-3.40)	2.70(1.89-3.40)	2.86(2.35-3.37)	(2.44-2.70)
7	45.0-49.9	3.26(2.20-4.32)	2.95(2.00-3.95)	3.08(2.39-3.77)	(2.84-2.99)
8	50.0-54.9	3.85(2.91-4.79)	3.25(2.27-3.80)	3.55(2.68-4.42)	(3.14-3.30)
9	55.0-59.9	4.14(3.08-5.20)	3.90(3.14-4.72)	3.95(3.04-4.86)	(3.44-3.57)
10	60.0-64.9	4.34(2.95-5.73)	4.15(2.66-4.15)	4.32(3.13-5.51)	(3.68-3.79)
11	65.0-69.9	4.14(2.82-5.46)	4.38(3.87-5.42)	4.50(3.20-5.50)	(3.93-4.18)
12	70.0-74.9	4.86(3.94-5.78)	4.39(4.01-4.83)	5.11(3.14-7.08)	
13	75.0-79.9	4.87(3.37-6.37)	4.67(3.39-5.55)	4.52(3.02-6.02)	
14	80.0-84.9	4.52(3.96-5.08)		3.50	
	Females				
15	15.0-19.9	1.04(0.60-1.48)	1.01(0.89-1.13)		(0.93-1.01)
16	20.0-24.9	1.40(0.91-1.89)	1.39(1.17-1.56)		(1.24-1.39)
17	25.0-29.9	1.75(1.23-2.27)	1.69(1.31-1.95)		(1.53-1.65)
18	30.0-34.9	1.98(1.35-2.61)	1.95(1.34-2.40)	2.22(1.95-2.49)	(1.80-1.92)
19	35.0-39.9	2.37(1.64-3.10)	2.33(1.69-3.26)	2.55(2.07-3.03)	(2.03-2.21)
20	40.0-44.9	2.63(1.69-3.57)	2.26(1.63-2.93)	2.73(2.18-3.28)	(2.27-2.52)
21	45.0-49.9	3.02(2.18-3.86)	2.81(2.22-3.10)	2.92(2.41-3.43)	(2.62-2.72)
22	50.0-54.9	3.24(2.24-4.24)	2.77(1.83-3.59)	3.04(2.47-3.61)	(2.63-2.80)
23	55.0-59.9	3.53(2.39-4.67)	2.98(2.29-4.06)	3.16(2.49-3.83)	(2.90-3.04)
24	60.0-64.9	3.65(2.93-4.37)	2.78[5]	3.20(2.59-3.81)	3.05
25	65.0-69.9	3.55(1.57-5.53)		3.48(2.96-4.00)	(2.73-3.00)
26	70.0-74.9	4.13(3.41-4.85)	3.49(3.26-3.72)	3.36(2.65-4.07)	3.39
27	75.0-79.9	3.90		3.18(2.75-3.61)[c]	2.90
28	80.0-84.9				2.90
29	85.0-89.9				2.90

/1/ The maximal volume of gas expelled from the lungs by forceful effort, following maximal inspiration. /2/ Subjects seated; Benedict-Roth type spirometer (Collins ventilometer) with the soda lime container and valves removed. /3/ All measurements made in recumbent position; Sanborn closed-circuit wet spirometer. /4/ Position not stated; wet spirometer. /5/ From single determination.

Contributors: (a) Ferris, B. G., Jr., (b) Morrow, P. E., (c) Morse, M., (d) Shock, N. W., (e) Whittenberger, J. L.

References: [1] Ferris, B. G., Jr., Whittenberger, J. L., and Gallagher, J. R., Pediatrics, Springf. 9:659, 1952. [2] Ferris, B. G., Jr., and Smith, C. W., ibid 12:341, 1953. [3] Morse, M., Schlutz, F. W., and Cassels, D. E., J. Clin. Invest. 31:380, 1952. [4] Morse, M., Univ. of Chicago, unpublished. [5] Shock, N. W., and Norris, A. H., Gerontology Branch, National Institutes of Health, unpublished. [6] Stewart, C. A., Am. J. Dis. Child. 24:451, 1922.

34. VITAL CAPACITY VS SURFACE AREA: CHILDREN AND ADOLESCENTS

Ventilatory values are corrected to BTPS conditions (cf Page 1). Values in parentheses are ranges and conform to estimate "b" of the 95% range in data of Ferris and to estimate "c" in data of Morse (cf Introduction).

	Body Surface Area sq m	Vital Capacity, L[1]	
		Ferris[2]	Morse[3]
	(A)	(B)	(C)
		Males	
1	0.70-0.89	1.52(0.84-2.20)	1.15(0.92-1.38)
2	0.90-0.99	1.63(1.33-1.93)	1.83[4]
3	1.00-1.09	1.99(1.47-2.51)	2.12(1.86-2.45)
4	1.10-1.19	2.10(1.74-2.46)	2.22(1.66-2.58)
5	1.20-1.29	2.47(1.63-3.31)	2.41(1.86-2.97)
6	1.30-1.39	2.57(1.75-3.39)	2.57(1.89-3.38)
7	1.40-1.49	3.36(2.68-4.04)	3.01(2.15-3.95)
8	1.50-1.59	3.53(2.31-4.75)	3.33(2.88-3.75)
9	1.60-1.69	4.08(3.10-5.06)	3.71(2.66-4.72)
10	1.70-1.79	4.32(3.40-5.24)	4.12(3.32-4.76)
11	1.80-1.89	4.85(3.71-5.99)	4.48(3.87-5.29)
12	1.90-1.99	4.88(3.68-6.08)	5.11(4.83-5.42)
13	2.00-2.09	5.39(4.61-6.17)	4.78(4.01-5.55)
		Females	
14	0.60-0.79	1.12(0.72-1.52)	0.89[4]
15	0.80-0.89	1.38(0.86-2.90)	1.38(1.13-1.56)
16	0.90-0.99	1.64(1.06-2.22)	1.31(1.17-1.45)
17	1.00-1.09	1.84(1.32-2.36)	1.80(1.73-2.06)
18	1.10-1.19	2.21(1.66-2.76)	2.00(1.70-2.25)
19	1.20-1.29	2.39(1.79-2.99)	2.11(1.63-2.56)
20	1.30-1.39	2.76(2.02-3.50)	2.25(2.16-2.34)
21	1.40-1.49	3.08(2.00-4.16)	2.65(1.83-3.26)
22	1.50-1.59	3.29(2.39-4.19)	2.87(2.29-4.06)
23	1.60-1.69	3.69(2.95-4.43)	3.18(2.72-3.59)
24	1.70-1.79	4.00(3.16-4.84)	
25	1.80-1.89	4.20(3.72-4.68)	3.49(3.26-3.72)

/1/ Maximal volume of gas expelled from lungs by forceful effort, following maximal inspiration. /2/ Subjects seated; body surface area obtained from DuBois nomogram; Benedict-Roth type spirometer (Collins ventilometer). /3/ All measurements made in recumbent position; Sanborn closed-circuit wet spirometer. /4/ From single determination.

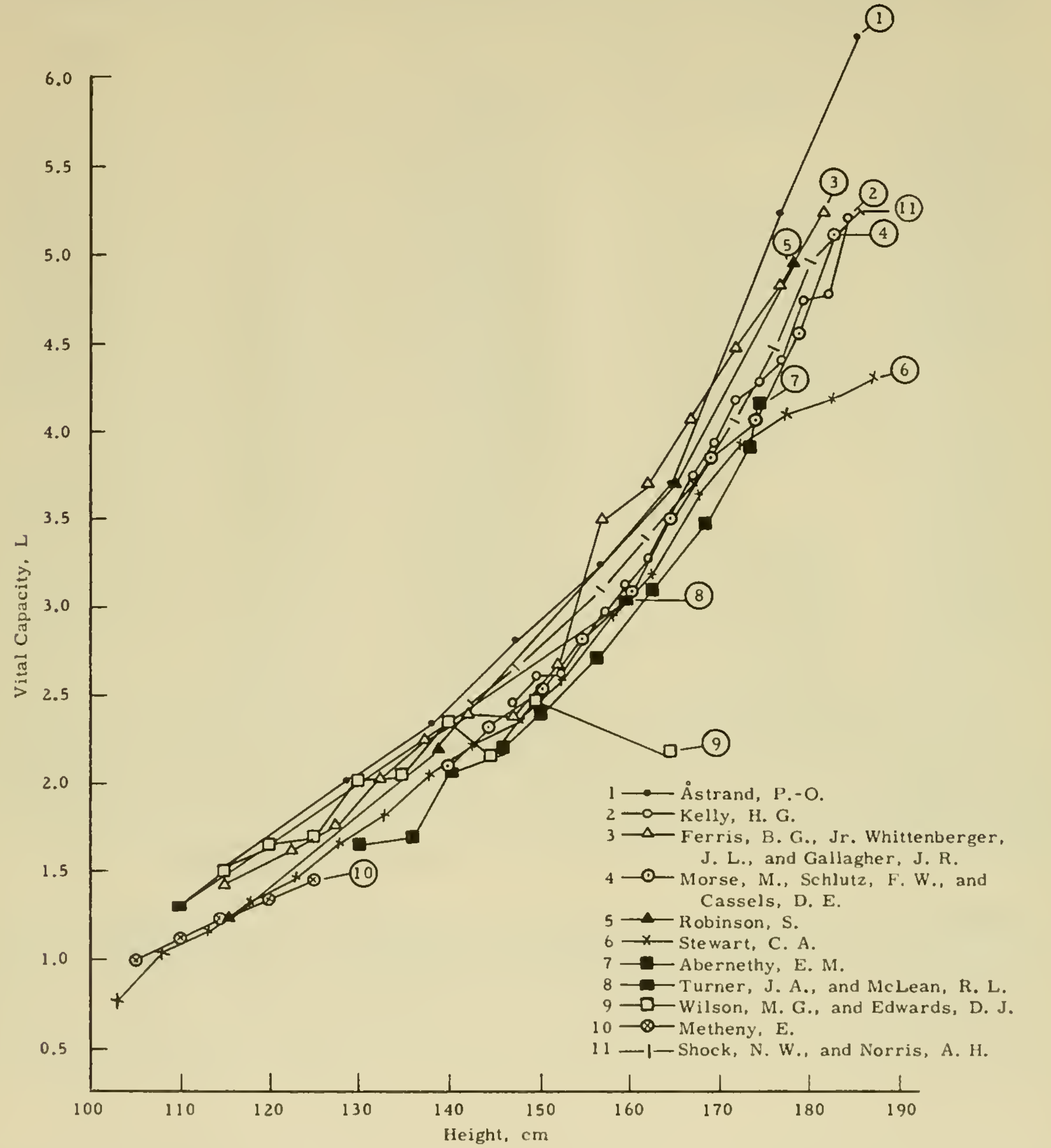
Contributors: (a) Ferris, B. G., Jr., (b) Morrow, P. E., (c) Morse, M., (d) Whittenberger, J. L.

References: [1] Ferris, B. G., Jr., Whittenberger, J. L., and Gallagher, J. R., Pediatrics, Springf. 9:659, 1952. [2] Ferris, B. G., and Smith, C. W., Pediatrics, Springf. 12:341, 1953. [3] Morse, M., Schlutz, F. W., and Cassels, D. E., J. Clin. Invest. 31:380, 1952. [4] Morse, M., Univ. of Chicago, unpublished.

35. VITAL CAPACITY VS STANDING HEIGHT: CHILDREN AND ADOLESCENTS

Data of Kelly and Stewart conform to ATPS conditions. All other data have been corrected to BTPS conditions (cf Page 1).

Part I: MALES



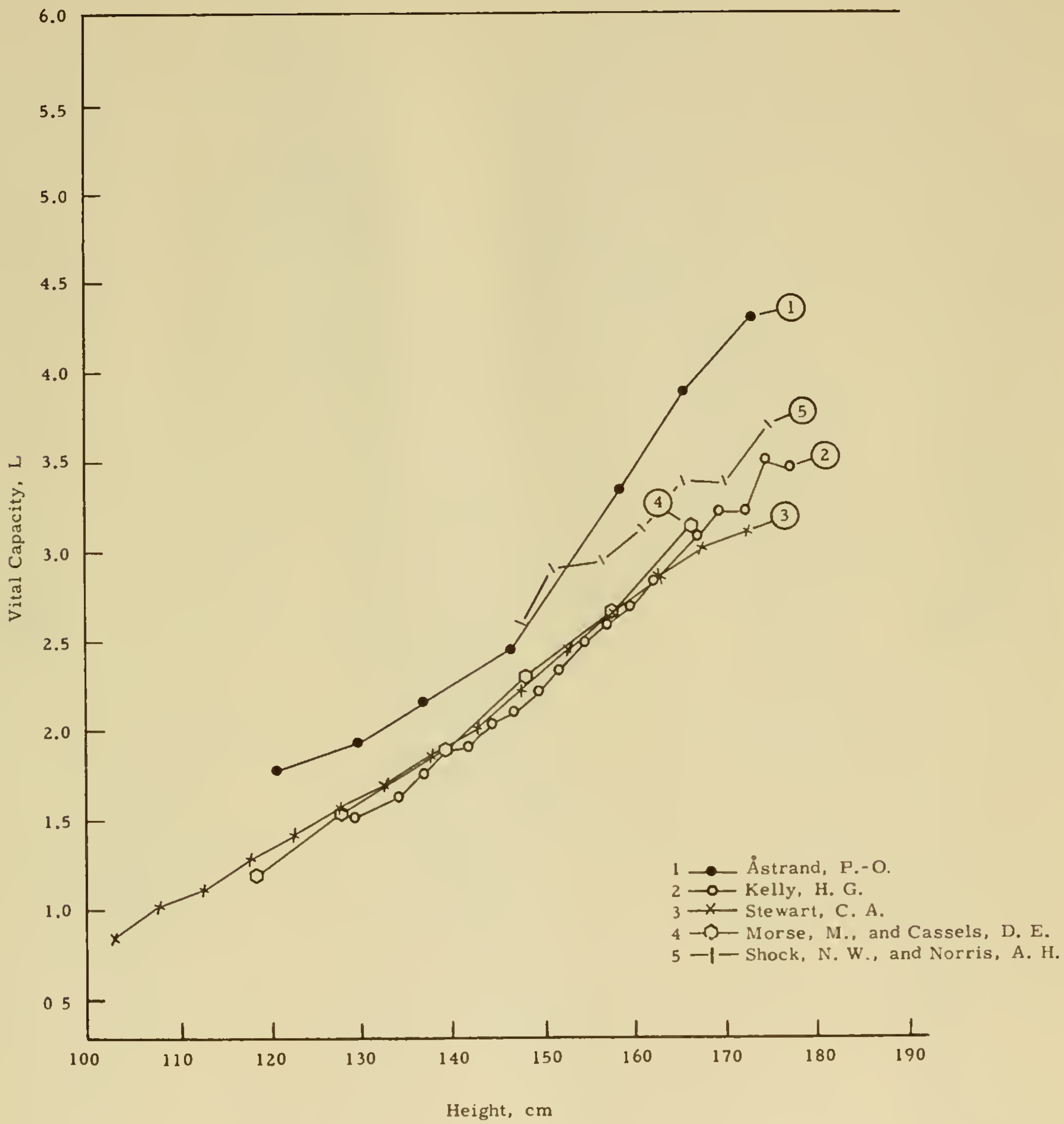
Contributors: (a) Morse, M., (b) Shock, N. W.

References: [1] Åstrand, P.-O., "Experimental Studies of Physical Working Capacity in Relation to Sex and Age," Copenhagen: Ejnar Munksgaard, 1952. [2] Kelly, H. G., "Studies in Child Welfare," 7:No. 5, Univ. of Iowa Press, 1933. [3] Ferris, B. G., Jr., Whittenberger, J. L., and Gallagher, J. R., Pediatrics 9:659, 1952. [4] Morse, M., Schlutz, F. W., and Cassels, D. E., J. Clin. Invest. 31:380, 1952. [5] Robinson, S., Arbeitsphysiologie 10:251, 1938. [6] Stewart, C. A., Am. J. Dis. Child. 24:451, 1922. [7] Abernethy, E. M., "Child Development," 1:No. 7, Nat. Res. Council, Wash., D. C., 1936. [8] Turner, J. A., McLean, R. L., Pediatrics 7:360, 1951. [9] Wilson, M. G., Edward, D. J., Am. J. Dis. Child. 22:443, 1921. [10] Metheny, E., "Studies in Child Welfare," 18:No. 2, Univ. of Iowa Press, 1933. [11] Shock, N. W., and Norris, A. H., Gerontology Branch, National Institutes of Health, unpublished.

35. VITAL CAPACITY VS STANDING HEIGHT: CHILDREN AND ADOLESCENTS (Concluded)

Data of Kelly and Stewart conform to ATPS conditions. All other data have been corrected to BTPS conditions (cf Page 1).

Part II: FEMALES



Contributors: (a) Morse, M., (b) Shock, N. W.

References: [1] Åstrand, P.-O., "Experimental Studies of Physical Working Capacity in Relation to Sex and Age," Copenhagen: Ejnar Munksgaard, 1952. [2] Kelly, H. G., "Studies in Child Welfare," 7:No. 5, Univ. of Iowa Press, 1933. [3] Stewart, C. A., Am. J. Dis. Child. 24:451, 1922. [4] Morse, M., and Cassels, D. E., unpublished. [5] Shock, N. W., and Norris, A. H., Gerontology Branch, National Institutes of Health, unpublished.

36. VITAL CAPACITY VS AGE AND STANDING HEIGHT: CHILDREN AND ADOLESCENTS

Volumes, measured in a wet spirometer, are in liters and conform to ATPS conditions (cf Page 1). Standing heights are for subjects in stocking feet.

	Age yr	Standing Height, cm 88	95	98	103	108	113	118	123	128	133	138	143	148	153	158	163	168	173	178	183	188
											Males											
1	5			0.84	0.77	0.98	0.97	0.93														
2	6				0.81	1.12	1.16	1.25	1.33													
3	7					1.08	1.21	1.30	1.40	1.62		2.20										
4	8						1.24	1.35	1.48	1.71	1.65	1.80										
5	9						1.40	1.45	1.54	1.67	1.79	1.99	2.07									
6	10							1.53	1.66	1.66	1.87	2.00	2.23	1.90								
7	11								1.46	1.81	1.83	2.07	2.15	2.18								
8	12								1.30	1.57	1.80	2.06	2.15	2.32	2.65	2.97	3.00					
9	13										1.91	2.13	2.24	2.38	2.55	2.77	3.28	3.40				
10	14											1.94	2.30	2.40	2.58	2.91	3.02	3.33	3.54	3.95		
11	15												2.45	2.57	2.73	2.97	3.20	3.67	3.89	3.86		
12	16												2.40	2.40	2.40	3.24	3.21	3.64	3.96	4.18		
13	17															2.83	2.85	3.81	3.97	4.26	4.05	4.30
14	18															2.75		3.93	4.13	4.20	4.40	
15	19																4.30	4.30	4.30			
											Females											
16	4	0.61	0.65	0.69	0.85																	
17	5			0.85	0.85	0.91	1.05	1.10														
18	6				0.81	1.03	1.08	1.28	1.32													
19	7				0.95	1.09	1.13	1.24	1.36	1.44	1.80											
20	8				0.90	1.00	1.23	1.31	1.44	1.45	1.78											
21	9						1.15	1.29	1.43	1.51	1.69	1.82	1.85									
22	10						1.07	1.33	1.42	1.59	1.68	1.82	1.98	2.18	2.15							
23	11							1.33	1.34	1.63	1.70	1.82	1.94	2.14	2.05							
24	12								1.45	1.73	1.70	1.93	2.00	2.11	2.35	2.53	2.95					
25	13									1.65	1.65	1.96	2.02	2.26	2.38	2.51	2.87	3.04				
26	14											2.15	2.20	2.29	2.47	2.68	2.82	3.13	3.10			
27	15												2.21	2.29	2.50	2.71	2.87	3.01				
28	16														2.73	2.79	2.73	2.85				
29	17														2.25		3.03	3.10				

Contributor: Morrow, P. E.

Reference: Stewart, C. A., Am. J. Dis. Child. 24:451, 1922.

37. VITAL CAPACITY VS AGE AND SITTING HEIGHT: CHILDREN AND ADOLESCENTS

Volumes, measured in a wet spirometer, are in liters and conform to ATPS conditions (cf Page 1).

	Age yr	Sitting Height, cm 51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93	95
	Males																							
1	5		0.95	0.80	0.91	1.03	1.01	1.15																
2	6			1.13	1.06	1.17	1.18	1.33	1.20															
3	7		1.00	1.15	1.15	1.18	1.30	1.32	1.39	1.46	2.20													
4	8				1.20	1.30	1.29	1.42	1.56	1.63	1.83													
5	9					1.40	1.52	1.50	1.60	1.76	1.80	1.99	2.50	2.57										
6	10						1.53	1.82	1.68	1.73	1.92	1.99	2.03	2.20	2.65									
7	11							1.50	1.77	1.78	1.98	2.09	2.11	2.18	2.50	2.50								
8	12								1.70	1.85	1.95	2.05	2.14	2.24	2.41	2.65	2.79	2.80						
9	13									1.80	2.13	2.07	2.27	2.31	2.42	2.60	2.81	3.01	3.33		4.00			
10	14											2.16	2.10	2.40	2.51	2.66	2.81	3.02	3.22	3.39	3.85	3.45		4.25
11	15												2.40	2.31	2.69	2.79	2.93	3.27	3.29	3.67	3.85	3.77		
12	16													2.39	2.45	2.67	3.62	3.19	3.37	3.61	3.91	4.13	4.30	4.30
13	17																	2.55	2.90	3.85	4.00	4.17	4.06	4.30
	Females																							
14	5	0.75	0.95	0.87	0.86	1.07																		
15	6		1.15	0.98	1.07	1.10	1.10	1.25	1.27															
16	7			0.90	1.09	1.10	1.16	1.35	1.40	1.33	1.40													
17	8				1.00	1.19	1.25	1.41	1.47	1.48	1.69	1.75												
18	9					1.17	1.38	1.43	1.42	1.54	1.74	1.85	2.00											
19	10					0.90	1.32	1.40	1.51	1.64	1.75	1.88	2.01	2.17	2.30	2.75								
20	11						1.25	1.43	1.61	1.61	1.77	1.86	1.94	1.97	2.05	2.12								
21	12							1.45	1.45	1.87	1.84	1.87	1.92	2.10	2.26	2.28	2.56	2.70						
22	13								1.70	1.60	1.93	2.00	1.93	2.15	2.24	2.44	2.47	2.71	2.97	2.88				
23	14												2.25	2.23	2.31	2.47	2.59	2.72	2.92	2.96	3.23			
24	15											2.00	2.00	2.15	2.24	2.57	2.69	2.82	2.85	3.03	3.09			
25	16															2.76	2.51	2.55	2.89	3.01				
26	17																2.25	2.70	3.02			3.10		
27	18																		3.10					

Contributor: Morrow, P. E.

Reference: Stewart, C. A., Am. J. Dis. Child. 24:451, 1922.

Ventilatory values have been corrected to BTPS conditions (cf Page 1). Data of Morse, Robinson, and Kaltreider are ranges and, except for data of Shock, conform to estimate "c" of the 95% range (cf Introduction). Data of Shock

	Age yr	Height cm	Weight kg	Surface Area sq m	Inspiratory Capacity[1] L	Expiratory Reserve Volume[2] L
	(A)	(B)	(C)	(D)	(E)	(F)
	Males					
1	6.0(5.8-6.5)	115(107-126)	20.1(17.6-29.0)	0.81(0.72-0.97)	0.99	0.27(0.12-0.41)
2	9.6(9.5-9.7)	139.2(127.1-148.4)	34.3(25.7-41.6)	1.15(0.95-1.31)	1.70(1.42-1.86)	0.39(0.36-0.41)
3	10.5(10.0-10.9)	145.4(138.7-153.4)	38.4(29.9-47.4)	1.25(1.09-1.39)	1.82(1.44-2.05)	0.46(0.42-0.52)
4	10.8(8.2-12.6)	139(131-149)	32.3(25.3-39.0)	1.12(0.98-1.39)	1.70	0.50(0.27-0.86)
5	11.5(11.2-11.9)	145.7(137.8-162.5)	35.3(28.8-50.7)	1.20(1.07-1.49)	1.77(1.49-2.07)	0.53(0.33-0.76)
6	12.5(12.0-12.9)	151.7(136.0-161.9)	42.6(32.0-77.3)	1.34(1.11-1.71)	2.13(1.55-2.87)	0.52(0.26-0.84)
7	13.4(13.0-13.9)	155.6(140.4-171.7)	45.9(33.9-71.6)	1.41(1.15-1.84)	2.17(1.32-3.69)	0.56(0.32-1.05)
8	14(13-15)	165(156-177)	55.8(41.7-67.4)	1.62(1.39-1.83)	2.89	0.82(0.49-1.28)
9	14.5(14.0-14.9)	163.8(143.4-183.7)	53.2(34.7-101.1)	1.57(1.18-2.11)	2.72(1.56-4.12)	0.72(0.48-1.08)
10	15.4(15.0-15.9)	170.5(151.7-185.4)	55.5(39.0-68.3)	1.64(1.30-1.90)	3.05(1.83-4.52)	0.80(0.52-1.16)
11	16.3(16.0-16.7)	173.9(156.4-190.0)	61.7(51.8-75.7)	1.74(1.57-2.02)	3.34(2.52-4.34)	0.85(0.55-1.25)
12	17.5(16.0-19.0)	179(163-190)	70.3(55.1-88.0)	1.91(1.58-2.15)	3.77	1.18(0.89-1.54)
13	22.9(16.3-29.5)	176.2(166.0-186.4)	72.5(50.1-94.9)	1.88(1.52-2.20)	3.79(2.75-4.83)	0.98(0.46-1.50)
14	24(20-29)	177(170-188)	72.9(63.4-84.4)	1.89(1.71-2.11)	3.86	1.39(0.96-1.83)
15	25.5(13.5-37.5)	173.8(156.6-191.0)	66.0(49.4-82.6)	1.79(1.46-2.11)		
16	26(24-29)	174.3(164.7-183.9)	77.5(39.1-115.9)	1.92(1.53-2.31)	3.42(1.95-4.89)	0.91(0.50-1.32)
17	27(17-37)					
18	33.9(4.7-63.1)	169.4(163.2-175.6)	62.1(19.9-104.3)	1.72(1.02-2.18)	2.99(1.65-4.33)	0.98(0.36-1.29)
19	34(30-39)	176.6(166.2-187.0)	74.2(52.4-96.0)	1.90(1.65-2.15)	3.19(1.58-4.79)	0.85(0.14-1.56)
20	35(31-38)	175(169-185)	77.5(60.7-85.2)	1.93(1.69-2.09)	3.78	0.98(0.37-1.87)
21	42.7(34.5-50.9)	171.7(157.8-185.6)	64.9(42.5-87.3)	1.78(1.38-2.10)		
22	44(40-48)	177(163-183)	75.6(63.5-86.2)	1.93(1.68-2.09)	3.59	0.69(0.23-2.20)
23	44(41-48)	173.2(162.8-183.6)	67.8(45.3-90.3)	1.81(1.57-2.05)	2.52(1.16-3.87)	0.82(0.23-1.40)
24	48.2(35.4-61.0)	170.5(156.1-184.7)	70.8(46.6-95.0)	1.82(1.40-2.18)	3.37(2.23-4.51)	0.69(0.07-1.31)
25	51(48-55)	172(156-180)	68.6(62.6-81.7)	1.82(1.60-2.01)	3.33	0.83(0.00-1.61)
26	53(47-62)					
27	54(50-59)	171.3(158.4-184.2)	63.0(46.2-79.8)	1.74(1.49-1.99)	2.53(1.33-3.73)	0.63(0.16-1.10)
28	54.3				2.89(1.25-4.53)	1.39(0.23-2.55)
29	58.0(33.2-82.8)	168.7(148.5-188.9)	63.6(38.8-88.4)	1.72(1.28-2.14)	2.47(1.59-3.35)	0.84(0.12-1.56)
30	59.6(48.8-70.4)	169.6(153.0-186.2)	66.3(49.1-83.5)	1.78(1.43-2.09)		
31	61.5(47.9-75.1)	169.0(159.4-178.6)	65.9(41.1-90.7)	1.77(1.38-2.08)	2.61(1.39-3.83)	1.01(0.23-1.79)
32	62(59-66)	173(166-180)	68.9(54.3-79.0)	1.83(1.58-1.99)	3.37	0.68(0.38-1.19)
33	64(60-68)	167.8(158.6-177.0)	63.5(44.9-82.1)	1.72(1.48-1.96)	2.21(0.93-3.48)	0.48(0.00-1.01)
34	73(70-77)	166.9(154.9-178.9)	63.2(36.7-89.7)	1.71(1.36-2.06)	1.90(1.09-2.71)	0.37(0.00-0.75)
35	77(71-91)	171(164-184)	66.9(57.6-75.6)	1.78(1.58-1.98)	2.73	0.47(0.18-0.87)
36	83(80-87)	163.9(147.8-180.0)	59.7(39.9-79.5)	1.65(1.34-1.96)	1.82(0.83-2.82)	0.45(0.00-1.09)
	Females					
37	7.1(6.4-7.9)	126(121-129)	25.2(21.2-31.5)	0.94(0.88-1.05)	1.20(1.04-1.41)	0.28(0.21-0.40)
38	8.2(8.0-8.4)	133(127-145)	29.5(23.2-37.4)	1.04(0.91-1.23)	1.24(1.01-1.54)	0.27(0.17-0.36)
39	9.6(9.0-9.9)	139(135-142)	34.6(26.0-44.9)	1.15(1.01-1.30)	1.53(1.30-1.95)	0.38(0.21-0.52)
40	10.2(10.1-10.6)	148(146-150)	46.7(36.6-63.2)	1.37(1.23-1.58)	1.95(1.81-2.15)	0.45(0.35-0.63)
41	11.6(11.1-11.9)	149(132-167)	37.2(27.7-46.6)	1.25(1.06-1.44)	1.71(1.36-1.92)	0.44(0.27-0.68)
42	12.6(12.2-12.9)	156(137-172)	45.3(31.6-54.0)	1.41(1.10-1.62)	2.05(1.55-2.51)	0.53(0.28-0.66)
43	13.3(13.0-13.7)	160(148-169)	51.2(39.2-59.0)	1.51(1.40-1.60)	2.45(1.94-3.27)	0.55(0.34-0.79)
44	14.5(14.3-14.8)	165(162-169)	52.4(49.6-54.3)	1.57(1.52-1.60)	2.42(2.06-2.80)	0.63(0.50-0.79)
45	15.4(15.1-15.8)	166(160-172)	63.7(53.2-74.4)	1.70(1.54-1.85)	2.43(1.93-2.87)	0.59(0.42-0.85)
46	21.5(18.0-23.7)	165.8(148.8-176.5)	62.0(42.4-88.4)	1.68(1.34-1.98)	2.69(1.50-3.85)	0.63(0.33-1.17)
47	23.1(16.3-29.9)	163.4(155.0-171.8)	57.2(38.4-76.0)	1.62(1.34-1.87)	2.42(1.70-3.14)	0.73(0.35-1.11)
48	25.1(12.7-37.5)	161.8(149.4-174.2)	59.2(37.0-81.4)			
49	25.2(24.3-28.5)	165.7(158.4-173.2)	58.9(47.6-70.4)	1.65(1.53-1.81)	2.62(1.92-3.31)	0.64(0.36-0.88)
50	33(30-37)	164.2(152.2-175.0)	60.5(50.2-79.5)	1.64(1.47-1.96)	2.72(2.06-3.35)	0.69(0.50-0.84)
51	43.3(36.1-50.5)	164.0(150.4-177.6)	62.6(32.0-93.2)	1.68(1.22-2.10)		
52	48.4(21.6-75.2)	163.6(153.4-173.8)	61.9(45.9-77.9)	1.67(1.41-1.89)	2.38(1.56-3.20)	0.59(0.00-1.19)
53	59.8(41.8-77.8)	158.4(145.0-171.8)	67.2(45.2-89.2)	1.68(1.35-1.98)		
54	60.9				1.96(1.06-2.86)	0.44(0.00-0.94)

/1/ Inspiratory capacity = maximal volume of air that can be taken into the lungs beyond the normal expiratory level. expiration. /3/ Vital capacity = inspiratory capacity + expiratory reserve volume. /4/ Residual volume = volume of residual capacity. /6/ Functional residual capacity = volume of air left in lungs after normal expiration.

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were obtained using closed-circuit wet spirometer method (modification of Christie method). Values in parentheses conform to estimate "b."

Vital Capacity[3] L	Residual Volume[4] L	Total Lung Capacity[5] L	Functional Residual Capacity[6] L	Reference	
(G)	(H)	(I)	(J)	(K)	
Males					
1.26(0.92-1.67)	0.39(0.26-0.58)	1.65(1.35-2.06)	0.66(0.5-0.95)	1	1
2.09(1.83-2.22)	0.46(0.41-0.51)	2.48(2.24-2.73)	0.84(0.82-0.84)	2	2
2.28(1.86-2.53)	0.62(0.34-0.82)	2.95(2.39-3.36)	1.09(0.76-1.34)	3	3
2.20(1.97-2.74)	0.57(0.45-0.95)	2.78(2.43-3.69)	1.07(0.80-1.48)	1	4
2.30(1.86-2.70)	0.60(3.60-0.86)	2.92(2.49-3.56)	1.11(0.88-1.62)	3	5
2.65(1.81-3.40)	0.56(0.29-0.88)	3.19(2.63-4.14)	1.11(0.80-1.58)	3	6
2.73(1.66-4.33)	0.64(0.29-1.06)	3.27(2.17-4.59)	1.20(0.68-1.87)	3	7
3.71(2.93-5.07)	0.95(0.70-1.52)	4.67(3.63-6.15)	1.77(1.23-2.46)	1	8
3.45(2.06-5.09)	0.85(0.56-1.52)	4.36(2.88-6.54)	1.59(1.10-2.46)	3	9
3.84(2.36-5.42)	0.97(0.59-1.30)	4.97(3.86-6.66)	1.80(1.28-2.41)	3	10
4.19(3.10-5.55)	0.98(0.61-1.29)	5.13(3.79-6.36)	1.80(1.27-2.25)	3	11
4.95(4.12-5.98)	1.30(0.97-1.75)	6.25(5.23-7.58)	2.48(2.05-3.14)	1	12
4.78(3.60-5.96)	1.19(0.49-1.89)	5.97(4.35-7.59)	2.18(1.18-3.18)	4	13
5.25(4.20-6.03)	1.66(0.84-2.94)	6.81(5.04-8.37)	3.05(1.91-4.45)	1	14
4.01(2.77-5.25)				5	15
4.31(2.66-5.96)	1.28(0.57-1.99)	5.59(3.69-7.49)	2.19(1.25-3.13)	6	16
			3.15(2.39-4.60)	7	17
3.98(2.02-5.94)	1.46(0.44-2.48)	5.43(3.95-6.91)	2.44(1.10-3.78)	8	18
4.03(2.17-5.89)	1.45(0.66-2.24)	5.43(3.14-7.73)	2.29(1.00-3.59)	6	19
4.76(3.83-6.49)	1.60(1.27-2.12)	6.36(5.30-8.48)	2.57(1.84-3.92)	1	20
4.16(3.20-5.12)				5	21
4.28(3.76-5.16)	1.48(0.66-2.24)	5.77(4.42-7.05)	2.17(1.27-2.97)	1	22
3.36(1.81-4.91)	1.64(0.68-2.60)	4.97(3.36-6.59)	2.46(1.59-3.32)	6	23
4.07(2.83-5.31)	1.30(0.48-2.12)	5.37(3.69-7.05)	2.00(1.00-3.00)	4	24
4.16(3.60-5.52)	1.81(1.00-2.38)	6.31(5.33-7.90)	2.61(1.63-3.46)	1	25
			3.16(2.16-3.91)	7	26
3.17(1.89-4.44)	2.22(0.84-3.59)	5.39(3.97-6.80)	2.80(1.32-4.38)	6	27
4.26(2.38-6.14)		6.80(4.42-9.18)	3.90(2.54-5.26)	9	28
3.31(2.11-4.51)	1.78(1.02-2.54)	5.09(3.57-6.61)	2.62(1.42-3.82)	10	29
3.42(1.76-5.08)				5	30
3.48(2.52-4.44)	2.43(1.43-3.43)	5.92(4.78-7.06)	3.44(1.96-4.92)	11	31
4.05(3.45-5.04)	1.72(1.43-2.39)	5.77(4.34-6.73)	2.39(1.81-2.82)	1	32
2.69(1.18-4.20)	1.87(0.67-3.07)	4.57(3.08-6.06)	2.38(1.38-3.38)	6	33
2.28(1.35-3.20)	2.34(1.16-3.52)	4.62(3.05-6.18)	2.73(1.39-4.06)	6	34
3.20(2.61-3.40)	1.92(1.71-2.52)	5.12(4.33-7.01)	2.73(1.89-3.39)	1	35
2.27(0.78-3.75)	2.21(1.01-3.41)	4.47(2.20-6.75)	2.65(1.05-4.25)	6	36
Females					
1.53(1.31-1.81)	0.44(0.23-0.61)	1.95(1.71-2.27)	0.75(0.62-0.86)	2	37
1.51(1.17-1.90)	0.50(0.30-0.67)	1.91(1.64-2.22)	0.77(0.51-0.94)	2	38
1.91(1.70-2.30)	0.60(0.21-0.75)	2.55(2.16-2.97)	0.96(0.73-1.14)	2	39
2.40(2.16-2.78)	0.72(0.66-0.79)	2.93(2.82-3.05)	1.08(1.01-1.15)	2	40
2.15(1.63-2.67)	0.66(0.25-1.16)	2.81(2.25-3.84)	1.11(0.80-1.84)	2	41
2.58(1.83-3.10)	0.75(0.48-1.28)	3.38(2.39-4.36)	1.28(0.84-1.87)	2	42
3.00(2.29-4.06)	0.90(0.29-1.48)	3.92(2.57-4.84)	1.45(0.63-2.12)	2	43
3.05(2.66-3.59)	0.71(0.57-1.04)	3.76(3.26-4.63)	1.34(1.14-1.83)	2	44
3.02(2.50-3.72)	1.31(0.98-1.77)	4.09(3.58-5.02)	1.80(1.48-2.19)	2	45
3.32(1.88-4.74)	1.03(0.66-1.39)	4.16(3.16-5.60)	1.67(1.14-2.17)	2	46
3.14(2.32-3.96)	1.10(0.50-1.70)	4.24(3.10-5.38)	1.82(1.04-2.60)	4	47
3.06(1.96-4.16)				5	48
3.25(2.27-4.13)	1.19(0.73-1.62)	4.44(3.89-5.40)	1.83(1.49-2.09)	2	49
3.41(2.58-4.20)	1.21(0.98-1.51)	4.74(3.56-5.71)	1.93(1.50-2.36)	2	50
2.83(2.03-3.63)				5	51
2.98(1.72-4.24)	1.40(0.64-2.16)	4.38(2.82-5.94)	2.00(0.84-3.16)	10	52
2.43(1.37-3.49)				5	53
2.34(1.44-3.24)	1.78(0.98-2.58)	4.14(2.78-5.50)	2.22(1.16-3.28)	11	54

/2/ Expiratory reserve volume = maximal volume of air that can be voluntarily expelled from the lungs after a normal air left in lungs after reserve volume has been expelled. /5/ Total lung capacity = inspiratory capacity + functional

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39. EFFECT OF POSTURAL CHANGE OF LUNG VOLUMES: MAN

Values for supine and sitting positions are expressed as per cent of total lung capacity. The tidal volume is variable and can be assumed to be 10-15%. Values are for adult males less than 30 years of age, and for healthy females 18-34 years.

	Characteristic	Male		Female		Variation with Change of Posture[2]	Reference
		Supine[1] %	Sitting %	Supine %	Sitting %	%	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Residual volume	21.8	23.9[1]	25.9	28.2[1]	-20.9	B, 1, 2, a;C, 3-9, a; D, 1, a;E, 3-5, a; F, 1, 10, a
2	Expiratory reserve volume	18.5	27.9[1]	17.0		-42.5	C, 7, 8, a;B, 1, 2, a; F, 1, 10, 11, a;D, 1, a
3	Inspiratory capacity[3]	59.7	48.2[4]	57.1		11.2	B, 1, 2, a;F, 1, 10, a; D, 1, a
4	Vital capacity	78.2	76.1[4]	74.1	71.8	-4.8	B, 1, 2, a;D, 1, a; F, 1, 10-14
5	Total capacity	100.0	100.0[4]	100.0	100.0	-9.8	B, 1, 2, a;D, 1, a; F, 1, 10

/1/ Mean of averages. /2/ Mean values. /3/ Tidal volume + inspiratory reserve volume. /4/ Computed.

Contributor: (a) Rahn, H.

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40. EFFECT OF PREGNANCY ON LUNG VOLUMES AND OTHER VENTILATORY VARIABLES: MAN

Ranges in parentheses are estimate "b" of the 95% range (cf Introduction).

	Variable	Pregnancy, Lunar Month							Postpartum, Month		Method
		IV	V	VI	VII	VIII	IX	X	I	VI	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
1	Respiratory rate, breaths/min	16	15	16	16	16	16	16(12-20)	17	15(11-19)	Spirometer.
2	Tidal volume, L	0.56	0.59	0.61	0.61	0.65	0.70	0.7(0.4-1.0)	0.55	0.5(0.2-0.8)	Spirometer.
3	Minute volume, L/min	8.7	9.1	10.0	9.7	10.3	11.0	10.3(7.3-13.6)	9.5	7.3(4.3-10.3)	Spirometer.
4	Ventilatory equivalent, ml air/ml O_2	3.3	3.5	3.6	3.5	3.6	3.7	3.3(1.3-5.3)	3.4	3.0(1.0-5.0)	Minute volume/O_2 consumption.
5	Maximal breathing capacity, L/min	97	99	97	96	97	97	96(74-118)	92	102(80-124)	Douglas bag.
6	Total lung capacity, L	4.2	4.2	4.2	4.1	4.3	4.1	4.1(3.5-4.7)	4.1	4.2(3.6-4.8)	Residual volume + vital capacity.
7	Vital capacity, L	3.2	3.2	3.2	3.2	3.3	3.3	3.3(2.9-3.7)	3.1	3.3(2.8-3.8)	Spirometer.
8	Inspiratory capacity, L	2.6	2.7	2.7	2.7	2.7	2.7	2.7(2.3-3.1)	2.5	2.6(2.2-3.0)	Spirometer.
9	Expiratory reserve volume, L	0.65	0.65	0.65	0.61	0.63	0.56	0.55(0.3-0.8)	0.56	0.65(0.4-0.9)	Spirometer.
10	Functional reserve capacity, L	1.6	1.6	1.6	1.5	1.5	1.4	1.3(1.0-1.6)	1.5	1.6(1.3-1.9)	Open-circuit method.
11	Residual volume, L	1.0	1.0	1.0	0.9	0.9	0.8	0.8(0.6-1.0)	1.0	1.0(0.8-1.2)	Functional residual capacity-expiratory reserve.

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Reference: Adapted from Cugell, D. W., et al, Am. Rev. Tuberc. 67:568, 1953.

Values, unless otherwise specified, are for the resting state.

	Animal	Body Weight kg	Condition	Respiratory Rate breaths/min	Tidal Volume[1] ml	Minute Volume L/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Mammals						
1	Man, ♂	68.5	Resting	11.7(10.1-13.1)	750(575-895)	7.43(5.8-10.3)	1
2			Light work	17.1(15.7-18.2)	1673(1510-1770)	28.6(27.3-30.9)	
3			Heavy work	21.2(18.6-23.3)	2030(1900-2110)	42.9(39.3-45.2)	
4	♀	54	Resting	11.7(10.4-13.0)	339(285-393)	4.5(4.0-5.1)	1
5			Light work	19.0	860(836-885)	16.3(15.9-16.8)	
6			Heavy work	30.0(25.0-35.3)	880(490-1270)	24.5(17.3-31.8)	
7	Beaver (Castor canadensis)	18		16			2
8	Cat (Felis catus)	2.45		26	12.4	0.322	3
	Cow (Bos taurus)						
9	Hereford, heifer	144	Lying	34	1400	46	4
10			Standing	32	1500	49	
11	Holstein, heifer	164	Lying	35	1700	59	4
12			Standing	31	2000	61	
13	Guernsey, full-grown	410	Lying	30	3100	93	4
14			Standing	29	3700	107	
15	Hereford, full-grown	422	Lying	30	3400	102	4
16			Standing	29	3800	109	
17	Holstein, full-grown	514	Lying	30	3400	104	4
18			Standing	27	4200	114	
19	Jersey, full-grown	403	Lying	30	2700	82	4
20			Standing	27	3400	92	
21	Dog (Canis familiaris)[2]	30.5		16(11-18)	432	6.1(5.1-7.4)	b
22		28.6		17(11-21)	302	5.3(4.9-5.4)	
23		19.1		22(13-37)	251	5.5(4.5-6.4)	
24		16.4		13(12-16)	296	4.1(3.3-4.9)	
25	Guinea pig (Cavia cobaya)	0.471		90(69-104)	1.8(1.0-3.9)	0.16(0.09-0.38)	5
26	Hamster (Mesocricetus auratus)	0.091		74(33-127)	0.8(0.42-1.2)	0.05(0.025-0.083)	5
27	Horse (Equus caballus)[3]	696		11.9(10.6-13.6)	9060(8520-9680)	107	6
28	Manatee, Florida (Trichechus latirostris)	250		7(6-8)	7000(5000-9000)	45(35-60)	7
29	Marmot (Marmota marmota)	2.13	Awake[4]	8.0	22	0.174	8
30			Hibernating[5]	0.68	13(11.3-14.8)	0.0089	
31	Monkey (Macaca rhesus)	2.68		40(31-52)	21(9.8-29)	0.86(0.31-1.41)	5
32	Mouse (Mus musculus)	0.0198		163(84-230)	0.15(0.09-0.23)	0.023(0.011-0.036)	5
33	Porpoise (Tursiops truncatus)[6]	170		1.1(0.9-1.3)	9000(8000-10,000)	9.7(9.0-10.4)	9
34	Rabbit (Lepus cuniculus)	2.07				0.8(0.27-1.2)	5
35	Rabbit, pigmented			69	21	1.45	10
36	White			53	19	1.02	11
37	Rat, cotton (Sigmodon hispidus)	0.77		94.5(75-115)	0.35(0.24-0.70)	0.04(0.023-0.071)	5
38	White (Rattus norvegicus)	0.112		85.5(66-114)	0.86(0.60-1.25)	0.074(0.05-0.102)	5
39	Seal (Phoca vitulina)[7]	27.5(15-30)		9(6-12)		3.97	12
40	Sheep, Dorset ewe	63		19	310	5.7	5
41	Sloth (Choleopus hoffmani)	4.5		13		0.844(0.78-0.96)	13
42	(Bradypus griseus)	3.1		6.2(4.5-8.0)		0.485(0.33-0.73)	
43	Swine (Sus scrofa), ♂	225				37	6
	Birds						
44	Canary			108(96-120)			14
45	Chicken, ♂			17(12-21)	45		14
46	♀			28.5(20-37)			

/1/ Air inspired or expired in one respiration. /2/ Measurements made after 30-min rest in hammock, at 24°C; values corrected to BTPS conditions. /3/ Percheron gelding. /4/ Rectal temperature = 37.8°C. /5/ Rectal temperature = 5-6°C. /6/ Captive animal. /7/ Cheyne-Stokes respiration.

Values, unless otherwise specified, are for the resting state.

	Animal	Body Weight kg	Condition	Respiratory Rate breaths/min	Tidal Volume[1] ml	Minute Volume L/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Birds (Concluded)						
47	Duck, ♂			42	36.5(35-38)[8]		14
48	♀			110			
49	Goose, ♂			20			14
50	♀			40			
51	Pigeon			27.5(25-30)	4.8(4.5-5.2)[9]		14
52	Turkey			13.4[10]			14
	Reptile						
53	Turtle (Malaclemys centrata)[11]	(0.65-0.72)		3.7	14	0.051	15

/1/ Air inspired or expired in one respiration. /8/ Standing; supine, 30. /9/ Standing; supine, 4.7. /10/ Also reported, ♂28, ♀49. /11/ Diamondback terrapin; periodic cycles at (24-29)°C.

Contributors: (a) Stroud, R., and Forster, R. E., (b) Hemingway, A., (c) Elisberg, E. I., (d) McCutcheon, F. H.

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42. RESPIRATORY RATE, TIDAL AND MINUTE VOLUMES: INFANTS

Data are from individual resting infants as measured by body plethysmograph. Ranges, in parentheses, are estimate "c" of the 95% range (cf Introduction).

	Age da	Weight kg	Respiratory Rate breaths/min	Minute Volume cc/min	Tidal Volume, Mean cc
	(A)	(B)	(C)	(D)	(E)
1	0.2	3.12	19.0(14-21)	349(313-375)	18.4
2	0.3	3.52	22.7(20-25)	539(501-585)	23.7
3	0.5	3.57	26.0(23-30)	542(444-598)	20.8
4	0.5	3.83	31.0(29-34)	651(591-696)	21.0
5	0.5[1]	3.74	28.3(25-33)	557(479-646)	19.8
6	Average	3.6	25.4	527.6	20.7
7	6	3.91	26.6(18-33)	754(646-813)	28.3
8	6	3.18	28.8(25-36)	535(479-563)	18.5
9	6	3.66	29.1(22-33)	466(438-485)	16.0
10	7	5.0	28.9(20-34)	795(708-855)	27.5
11	7[1]	3.74	28.4(25-32)	526(480-563)	18.5
12	7	3.06	36.0(32-40)	598(543-668)	16.6
13	7	3.29	22.4(22-24)	384(354-459)	17.1
14	Average	3.69	28.6	579.7	20.5

/1/ Lines 5 and 11 are for the same infant.

Contributor: Smith, C. A.

Reference: Cross, K. W., J. Physiol., Lond. 109:459, 1949.

43. TIDAL AND MINUTE VOLUMES: MAN

Values in parentheses are ranges. Letter superscript identifies type of range (cf Introduction).

	Age yr	Sex	Position	Tidal Volume[1] ml	Minute Volume[2] L/min	Method	Gaseous Conditions[3]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Infant, premature[4]	♂♀	Supine	11.5(6.1-17)[d]	0.396(0.160-0.646)[c]	Plethysmograph	Amb	1
2		♂♀	Supine	13.3(8.4-17.3)[c]	0.430(0.281-0.581)[c]	Plethysmograph	ATPS	2
3		♂♀	Supine	12.3(4.5-17.2)[c]	0.698(0.304-1.225)[c]	Plethysmograph	ATPS	3
4	Newborn, full-term[4]	♂♀	Supine	16.5(6.9-26.8)[c]	0.731(0.413-1.13)[c]	Pneumograph	ATPS	4
5		♂♀	Supine	27.0(9.7-53.1)[c]	1.08(0.354-2.01)[c]	Plethysmograph	Amb	5
6		♂♀	Supine	19.8(9.7-30.5)[c]	0.851(0.225-1.83)[d]	Plethysmograph	Amb	6
7		♂♀	Prone	16.7(10-27)[d]	0.721(0.433-1.41)[c]	Plethysmograph	BTPS	7
8		♂♀	Supine	16.8 (13.3-21.8)[c]	0.642(0.365-0.894)[c]	Plethysmograph	ATPS	2
9		♂♀	Supine	21.5(15-32)[d]	0.59(0.35-0.83)[d]	Plethysmograph	BTPS	8
10	5.7-14	♂♀	Upright	388(195-581)[b]		Spirometer	BTPS	9
11	11.7-12.2	♂	Supine	305(185-425)[b]	4.79(3.74-5.84)[b]	Spirometer	STPD	10
12		♀	Supine	289(189-389)[b]	4.54(3.07-6.01)[b]	Spirometer	STPD	10
13	13.7-14.2	♂	Supine	316(196-436)[b]	5.27(3.80-6.74)[b]	Spirometer	STPD	10
14		♀	Supine	315(235-395)[b]	4.86(3.60-6.12)[b]	Spirometer	STPD	10
15	15.7-16.2	♂	Supine	344(184-504)[b]	5.13(3.45-6.81)[b]	Spirometer	STPD	10
16		♀	Supine	282(162-402)[b]	4.21(2.53-5.89)[b]	Spirometer	STPD	10
17	18-27	♂	Supine	372(192-552)[b]	5.04(2.94-7.14)[b]	Spirometer	STPD	10
18		♀	Supine	319(139-499)[b]	4.45(2.14-6.76)[b]	Spirometer	STPD	10
19	27-43	♂	Supine	390(250-530)[b]	5.25(3.45-7.05)[b]	Spirometer	STPD	10
20		♀	Supine	338(205-471)[b]	4.63(3.11-6.15)[b]	Spirometer	STPD	10
21	40-49	♂	Supine	422(259-585)[b]	6.90(4.37-9.43)[b]	Spirometer	STPD	11
22	50-59	♂	Supine	427(284-569)[b]	6.95(4.96-8.93)[b]	Spirometer	STPD	11
23	60-69	♂	Supine	408(263-554)[b]	6.70(4.76-8.65)[b]	Spirometer	STPD	11
24	70-79	♂	Supine	377(231-523)[b]	6.87(4.41-9.32)[b]	Spirometer	STPD	11
25	80-89	♂	Supine	366(240-493)[b]	6.57(4.00-9.14)[b]	Spirometer	STPD	11
26	17-36	♂	Upright	773(520-1130)[c]	14.86(9.6-25.8)[c]	Pneumotachograph	BTPS	12
27	18-34	♀	Upright	480(300-980)[c]	6.86(4.24-13.1)[c]	Spirometer	BTPS	13
28	21-27	♂♀	Upright	508(398-685)[c]	7.61(7.34-7.90)[c]	Pneumotachograph	ATPS	14
29	20-32	♂♀	Upright	597(218-1307)[c]	9.0(4.1-14.0)[c]	Pneumotachograph	ATPS	15
30	22-28	♀	Semirecumbent	481(453-510)[c]	6.09(5.89-6.25)[c]	Spirometer	BTPS	16
31	18-38	♂	Semirecumbent	654(416-1131)[c]	9.33(7.07-11.3)[c]	Spirometer	BTPS	17
32	21-35	♂	Upright	504(387-583)[c]	5.39(4.54-7.60)[c]	Pneumotachograph	BTPS	18
33	26-35	♂	Semirecumbent	594(514-740)[c]	7.94(5.14-11.1)[c]	Spirometer	BTPS	16
34	22-40	♀	Semirecumbent	639(503-675)[c]	8.12(6.57-10.6)[c]	Spirometer	BTPS	17
35	35-61	♂	Upright	764(704-824)[b]	10.5(9.9-11.1)[b]	Spirometer	BTPS	19
36	Adult	♂♀	Upright	522(468-555)[c]	[illegible].27(6.10-11.4)[c]	Spirometer	ATPS	20
37	Adult	♂♀	Upright	616(315-745)[c]	8.73(4.9-12.2)[c]	Respirograph	ATPS	21
38	Adult	♂♀	Upright	651(350-975)[c]	11.1(6.7-14.3)[c]	Pneumotachograph	ATPS	22
39	Adult	♂♀	Upright	738(399-1107)[c]	8.37(4.56-14.3)[c]	Spirometer	ATPS	23
40	50-75	♂	Semirecumbent	343(111-575)[b]	10.6(5.92-14.2)[d]	Spirometer	BTPS	24
41	50-77	♀	Semirecumbent	281(30-533)[b]	9.18(4.68-13.1)[d]	Spirometer	BTPS	24
42	53-81	♂	Semirecumbent	521(330-643)[c]	8.61(6.05-12.1)[c]	Spirometer	BTPS	16

/1/ Air inspired or expired per breath. /2/ Respiration frequency x tidal volume. /3/ Amb = ambient conditions. i.e., plethysmograph was not at saturation. For conversion among respective categories of gaseous conditions, see Page 1. /4/ Within first 14 da of life.

Contributors: (a) Morrow, P. E., (b) Cohn, J. E., (c) Shock, N. W.

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Respiratory values are corrected to STPD conditions (cf Page 1). Determinations were made on fasting subjects compute frequency distributions. Ranges in parentheses conform to estimate "b" of the 95% range (cf Introduction). gasometer method; O_2 and CO_2 concentrations by Boothby-Sanford modification of Haldane technique; samples of DuBois nomogram.

	Age yr	Sex	Respiratory Rate breaths/min	Ventilation Volume		Tidal Volume[1]		Expired Air	
				L/min	L/sq m/min	cc/breath	cc/sq m/breath	% O_2	% CO_2
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	11.75-12.24	♂	16.3 (7.9-24.7)	4.79 (3.74-5.84)	3.81 (2.76-4.86)	305 (185-425)	242 (158-326)	16.99 (16.36-17.62)	3.49 (2.86-4.12)
2		♀	16.1 (9.8-22.4)	4.54 (3.07-6.01)	4.41 (2.57-4.25)	289 (189-389)	216 (132-300)	16.90 (16.27-17.53)	3.57 (2.94-4.20)
3	13.75-14.24	♂	17.0 (12.8-21.2)	5.27 (3.80-6.74)	3.55 (2.92-4.18)	316 (196-436)	212 (149-275)	16.84 (16.21-17.47)	3.58 (3.16-4.00)
4		♀	15.6 (11.4-19.8)	4.86 (3.60-6.12)	3.24 (2.40-4.08)	315 (235-395)	208 (145-271)	16.97 (16.34-17.60)	3.51 (2.88-4.14)
5	15.75-16.24	♂	15.6 (9.3-21.9)	5.13 (3.45-6.81)	2.98 (2.14-3.82)	344 (184-504)	200 (137-263)	16.35 (15.30-17.40)	4.01 (3.17-4.85)
6		♀	15.2 (8.9-21.5)	4.21 (2.53-5.89)	2.67 (1.83-3.51)	282 (162-402)	177 (193-240)	16.59 (15.12-18.06)	3.81 (2.97-4.65)
7	18.00-26.99	♂	14.0 (7.7-20.3)	5.04 (2.94-7.14)	2.76 (1.71-3.81)	372 (192-552)	203 (198-308)	16.48 (15.43-17.53)	3.80 (2.75-4.85)
8		♀	14.7 (4.2-25.2)	4.45 (2.14-6.76)	2.91 (1.86-3.96)	319 (139-499)	202 (176-328)	16.98 (15.72-18.24)	3.41 (2.36-4.46)
9	27.00-43.00	♂	13.7 (7.7-19.7)	5.25 (3.45-7.05)	2.93 (2.13-3.73)	390 (250-530)	218 (138-298)	16.90 (15.90-17.90)	3.53 (2.73-4.33)
10		♀	14.4 (6.8-22.0)	4.63 (3.11-6.15)	2.84 (1.70-3.98)	338 (205-471)	202 (126-278)	17.08 (16.32-17.84)	3.32 (2.56-4.08)
11	40-49	♂	16.8 (11.4-22.2)	6.90 (4.37-9.43)	3.97 (2.61-5.33)	422 (259-585)	243 (151-334)	17.03 (17.03-18.75)	2.58 (1.95-3.21)
12	50-59	♂	16.7 (11.3-22.1)	6.95 (4.96-8.93)	4.03 (2.69-5.37)	427 (284-569)	247 (165-328)	18.04 (17.16-18.92)	2.52 (1.79-3.25)
13	60-69	♂	16.9 (11.1-22.7)	6.70 (4.76-8.65)	3.93 (2.25-5.61)	408 (263-554)	239 (153-324)	18.12 (17.52-18.72)	2.44 (1.93-2.95)
14	70-79	♂	18.8 (11.6-25.9)	6.87 (4.41-9.32)	4.13 (2.78-5.48)	377 (231-523)	226 (153-299)	18.28 (17.60-18.96)	2.26 (1.64-2.88)
15	80-90	♂	18.2 (12.5-23.9)	6.57 (3.95-9.14)	4.03 (2.47-5.59)	366 (240-493)	223 (169-277)	18.43 (17.75-19.11)	2.14 (1.61-2.67)

/1/ Volume of gas entering or leaving respiratory tract with each breath.

Contributor: Shock, N. W.

References: [1] Lines 1-10: Shock, N. W., and Soley, M. H., J. Nutrit. 18:143, 1939. [2] Lines 11-15:

45. O_2 AND CO_2 PRESSURES IN ALVEOLAR AIR AND SUBCUTANEOUS TISSUE: MAN

All values for males, under resting conditions. Methods: A = alveolar air drawn by method of Haldane and Priestley. T = microanalysis of gas bubble in tissue by method of Krogh. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Gas	Alveolar Air			Subcutaneous Tissue			Reference
		Subjects no.	Method	Pressure mm Hg	Subjects no.	Method	Pressure mm Hg	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Oxygen	54	A	97.8(87-107)	5	T	22(15-24)	B-D, 1;E-G, 2
2	Carbon dioxide	54	A	40.9(36.4-47.0)	5	T	45(41-50)	B-D, 1;E-G, 2

Contributors: Bartels, H., and Opitz, E.

References: [1] Bartels, H., and Rodewald, G., Pflügers Arch. 256:113, 1952. [2] Seevers, M. H., Am. J. Physiol. 115:38, 1936.

in recumbent position after 20-minute rest period. Averages of six determinations for each subject were used to Techniques and apparatus: Siebe-Gorman half mask; 8 minute tests of basal O_2 consumption by Tissot open-circuit respiratory alveolar air by Haldane-Priestley technique; CO_2 analyses by Haldane apparatus; surface areas by

CO_2 Tension, Alveolar Air mm Hg	CO_2 Elimination			O_2 Consumption			Heat Production cal/sq m/hr	
	cc/min	cc/kg/min	cc/sq m/min	cc/min	cc/kg/min	cc/sq m/min		
(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	
41.0 (34.7-47.3)				195 (153-237)	5.15 (3.89-6.41)	154.5 (120.9-188.1)	45.03 (35.37-54.69)	1
40.1 (35.9-44.3)				189 (126-252)	4.46 (3.20-5.72)	140.8 (117.7-163.9)	40.99 (34.27-47.71)	2
42.2 (38.0-46.4)				223 (160-286)	4.65 (3.60-5.70)	149.7 (122.4-177.0)	43.46 (36.11-50.81)	3
39.4 (33.1-45.7)				198 (156-240)	3.90 (3.06-4.74)	130.1 (109.1-151.1)	37.96 (31.87-44.05)	4
42.1 (33.7-50.5)				244 (181-307)	4.13 (3.29-4.97)	141.8 (112.4-171.2)	41.13 (33.15-49.11)	5
38.8 (32.5-45.1)				187 (124-250)	3.43 (2.59-4.27)	117.9 (92.7-143.1)	34.29 (27.15-41.43)	6
43.0 (32.5-53.5)				232 (169-295)	3.43 (2.38-4.48)	125.9 (100.7-151.1)	36.57 (28.59-44.55)	7
41.6 (29.0-54.2)				187 (124-250)	3.38 (2.33-4.43)	118.3 (86.8-149.8)	34.28 (25.88-42.68)	8
42.7 (30.7-54.7)				218 (158-278)	3.39 (2.39-4.39)	122.1 (102.1-142.1)	35.44 (29.84-41.04)	9
40.0 (30.5-49.5)				186 (148-224)	3.13 (1.80-4.46)	112.5 (78.3-146.7)	32.63 (23.13-42.13)	10
	173.0 (132.0-215.0)	2.72 (2.08-3.36)	99.7 (81.1-118.2)	215 (152-278)	3.37 (2.55-4.19)	123.5 (94.9-152.0)	35.73 (27.99-43.47)	11
	171.0 (131.0-211.0)	2.72 (1.84-3.60)	98.9 (75.0-122.9)	211 (146-276)	3.35 (2.23-4.47)	121.9 (86.2-157.6)	34.50 (25.74-43.26)	12
	160.0 (119.0-201.0)	2.51 (1.78-3.24)	93.4 (72.2-114.7)	193 (141-245)	3.03 (2.18-3.88)	112.9 (87.4-138.4)	33.00 (25.95-40.05)	13
	150.9 (99.9-202.0)	2.49 (1.91-3.07)	90.5 (68.2-112.7)	188 (131-245)	3.12 (2.27-3.97)	113.1 (87.6-138.6)	32.60 (25.31-39.89)	14
	138.9 (89.0-189.5)	2.34 (1.66-3.02)	84.6 (62.9-106.3)	172 (106-238)	2.89 (1.99-3.79)	104.7 (73.1-136.2)	30.05 (20.94-39.16)	15

Shock, N. W., and Yiengst, M. J., J. Geront. 10:31, 1955.

46. VENTILATION AND O_2 UPTAKE, RIGHT VS LEFT LUNG: MAN

	Variable	Supine Position		Right Lateral Position	
		Right	Left	Right	Left
	(A)	(B)	(C)	(D)	(E)
1	Ventilation, %	52	48	53-54	46-47
2	Oxygen uptake, %	49-50	50-51	61-63	37-39

Contributor: Rahn, H.

References: [1] Inada, K., Kishimoto, S., Sato, A., and Watanabe, T., J. Thorac. Surg. 27:173, 1954.
[2] Rothstein, E., Landis, F. B., and Navodick, B. G., ibid 19:821, 1950.

For purposes of defining dead space, expiratory air is arbitrarily divided into two components: that which is like alveolar air, and that--called dead space--which is like the inspired air. Dead space can be considered for any inspired or expired gas, CO_2 being most often studied. There are many methods for measuring dead space, differing primarily with the way alveolar air is measured or computed. It has not been shown that any two methods give identical results, nor is it known exactly which geometric portion of the lung they measure. Until identical results can be shown, it is best that different methods be identified by different names. For CO_2 and O_2, dead space is subdivided by some into two parts: one, the conducting airway from nares to terminal bronchioles, the other, a portion of the tidal volume going to alveoli but wasted because of uneven distribution of blood and gas in the lung. The terms in most common use are: (1) Anatomic Dead Space. Strictly, this is the geometric volume of the conducting airway. The term is used both by those making plaster or other casts of the dead lung airway; and by many whose methods are thought to approximate this volume *in vivo*, the most widely used of which methods is Fowler's single-breath analysis of gas flow and concentration [1]. Other terms and methods believed to approximate this anatomic space are grouped in this section under the heading Anatomic. (2) Physiologic Dead Space. This term includes both anatomic and distribution dead space, and indicates the value of alveolar CO_2 tension obtained by measuring arterial CO_2 tension. Other methods also attempt to include distribution dead space; these are all grouped with the arterial CO_2 tension methods under the heading Physiologic. Those marked "Haldane-Priestley" are now felt by most investigators to be too large, because the alveolar tension obtained by a forced lung expiration is too high. Regarding other methods, it is not possible to be certain whether they belong in the Anatomic or Physiologic group. "Alveolar" dead space [2] is the difference between the physiologic dead space and the anatomic dead space (Fowler); it is one measure of the distribution dead space. "Parallel" dead space also refers to the distribution dead space, as determined by the isosaturation technique [3].

Contributor: Severinghaus, J. W.

References: [1] Fowler, W. S., Am. J. Physiol. 154:405, 1948. [2] Severinghaus, J. W., and Stufpel, M., J. Appl. Physiol. 10:335, 1957. [3] Pappenheimer, J. R., Fishman, A. P., and Borrero, L. M., ibid 4:855, 1952.

Part 1: AT REST

Values in parentheses conform to estimate "c" of the 95% range (cf Introduction).

	Age yr	Subjects no.	Sex	Dead Space L	Method	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
					Anatomic	
1	Young	5	♂	0.130(0.100-0.160)	Fractional sampling, analysis of expiratory CO_2.	1
2	19-38	45	♂	0.156(0.106-0.219)	Nitrogen (Lilly nitrogen meter).	2
3	20-25	2	♀	0.108(0.093-0.124)	Foreign gas (hydrogen).	3
4	24	1	♀	0.133		4
5	25-32	5	♂	0.144(0.098-0.164)		3
6	27-29	3	♂	0.122(0.089-0.143)		4
7	29-36	7	♂	0.164(0.145-0.215)	Isosaturation.	5
8	68-89	18	♂	0.235(0.127-0.370)	Continuous recording of expiratory CO_2 infrared gas analyzer.	6
9		7	♂	0.177(0.154-0.214)		7
10		1	♂	0.176	Isosaturation.	8
11		4	♂	0.155(0.109-0.181)	Foreign gas (hydrogen).	9
12		1	♂	0.144	Plaster cast.	10
13		1	♀	0.090	Isosaturation.	5
					Physiologic	
14	18-34	50	♀	0.144(0.041-0.449)	Alveolar CO_2 tension (Haldane-Priestley).	11
15	18-38	5	♂	0.189(0.128-0.259)	N_2 clearance.	12
16	18-39	8	♂	0.180(0.130-0.260)	H_2 clearance.	13
17	21-32	10	♂	0.173(0.052-0.223)	Arterial CO_2 tension.	14
18	21-32	4	♀	0.110(0.090-0.140)	H_2 clearance.	13
19	22	1	♂	0.151	Arterial CO_2 tension.	15
20	29-36	7	♂	0.174(0.140-0.208)	Isosaturation.	5
21		2	♂	0.165(0.142-0.189)	Alveolar CO_2 tension (Haldane-Priestley).	16
22		4	♂	0.194(0.158-0.228)	Arterial CO_2 tension.	17

Contributors: (a) Rossier, P. H., (b) Bateman, J. B., (c) Fishman, A. P., (d) Kaltreider, N. L., (e) Severinghaus, J. W.

References: [1] Hatch, T., Cook, K. M., and Palm, P. E., J. Appl. Physiol. 5:341, 1953. [2] Fowler, W. S., Am. J. Physiol. 154:405, 1948. [3] Siebeck, R., Deut. Arch. klin. Med. 102:390, 1911. [4] Siebeck, R., Scand. Arch. Physiol. 25:86, 1911. [5] Fishman, A. P., J. Clin. Invest. 33:469, 1954. [6] Tenney, S. M., and Miller, R. M., J. Appl. Physiol. 9:321, 1956. [7] DuBois, A. B., Fowler, R. C., Soffer, A., and Fenn, W. O., ibid 4:526, 1952. [8] Pappenheimer, J. R., Fishman, A. P., and Borrero, L. M., ibid 4:855, 1952. [9] Krogh, A., and Lindhard, J., J. Physiol. 47:30, 1913-14. [10] Loewy, A., Pflügers Arch. 58:416, 1894. [11] Hurtado, A., Fray, W. W., Kaltreider, N. L., and Brooks, W. D., J. Clin. Invest. 13:169, 1934. [12] Bateman, J. B., J. Appl. Physiol. 3:143, 1950. [13] Birath, G., Acta med. scand., suppl., 154, 1944. [14] Blickenstorfer, E., Schweiz. Zschr. Tuberk., 4:suppl. 1, 1947. [15] Enghoff, H., Upsala läk. fören. förh. 44:191, 1938. [16] Haldane, J. S., and Priestley, J. G., J. Physiol. 32:240, 1905. [17] De Coster, A., and Denolin, H., Acta clin. belg. 9:135, 1954.

Part II: DURING ACTIVITY

Values in parentheses conform to estimate "c" of the 95% range (cf Introduction). V_D = volume of dead space gas, V_T = tidal volume.

	Subjects no.	Sex	Activity	O_2 Consumption L/min	V_T L	V_D L	$\frac{V_D}{V_T} \times 100$ %	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
					Anatomic			
1	2	♂	Moderately			0.172		1
2	2	♂	severe work			0.211		1
3	2	♂	750 kg/min,			0.142		2
4	2	♂	bicycle ergometer			0.093		2
5	1	♂	Quiet breathing		0.580	0.168	29	3
6	1	♀			0.895	0.105	12	3
7	1	♂	Post-exercise		0.810	0.188	23	3
8	1	♀	hyperpnea		1.310	0.158	12	3
					Physiologic			
9	1	♂	At rest[1]		0.403	0.198	49	4
10	1	♂	Fast walking[1]		1.373	0.650	47	4
11	1	♂	Bed rest[1]	0.237	0.457	0.160	35	5
12	1	♂	Standing rest[1]	0.328	0.612	0.222	36	5
13	1	♂	Walking[1]	1.436(0.668-2.543)	2.014(1.271-3.145)	0.463(0.293-0.622)	23.5(20-27.5)	5
14	4	♂	Severe work		2.400(1.500-3.300)[2]	0.303(0.245-0.365)[2]	13.3(11-16)[2]	6
15	4	♂	(bicycle	2.500[2]	3.304(3.030-3.500)[2]	0.310(0.292-0.362)[2]	10(9-11)[2]	6
16	30	♂	ergometer)	1.200(0.400-2.000)[2]	1.348(0.570-2.020)[2]	0.315(0.155-0.470)[2]	24(22-27)[2]	7
17	2	♂		0.862[2]	1.276[2]	0.281[2]	22[2]	8
18	2	♂		1.538[2]	1.706[2]	0.360[2]	21[2]	8
19	1	♂		1.740(1.410-2.050)[3]	2.562(1.890-3.520)[3]	0.322(0.280-0.392)[3]	12.8(11-15)[3]	9
20	2	♂	Treadmill		0.450[1] (at rest)	0.120[1]	26.5[1]	10
21	2	♂			2.950[1] (at work)	0.555[1]	19[1]	10
22	3	♂		1.667(1.255-2.425)[2]	2.298(1.705-3.582)[2]	0.227(0.131-0.296)[2]	10.8(8-17)[2]	11
23	3	♂		2.042[2]	2.809[2]	0.377[2]	13.5[2]	11
24	3	♂		0.690[2]	0.762[2]	0.258[2]	33[2]	11
25	34	♂		1.080(0.810-1.350)[2]			15.1(0-31)[2]	12

/1/ Alveolar CO_2 tension method (Haldane-Priestley). /2/ Arterial CO_2 tension method. /3/ Fractional sampling of expiratory gas, CO_2 analysis.

Contributors: (a) Rossier, P. H., (b) Severinghaus, J. W.

References: [1] Siebeck, R., Scand. Arch. Physiol. 25:81, 1911. [2] Krogh, A., and Lindhard, K., J. Physiol. 47:30, 1913-1914. [3] Fowler, W. S., Am. J. Physiol. 154:405, 1948. [4] Henderson, Y., Chillingworth, F. P., and Whitney, J. L., ibid 38:1, 1915. [5] Douglas, C. G., and Haldane, J. S., J. Physiol. 45:235, 1912. [6] Asmussen, E., and Nielsen, M., Acta physiol. scand. 38:1, 1956. [7] Rossier, P. H., and Buhlmann, A., unpublished. [8] Houston, C. S., and Riley, R. L., Am. J. Physiol. 149:565, 1947. [9] Aitken, R. S., and Clark-Kennedy, A. E., J. Physiol. 65:389, 1928. [10] Bannister, R. G., Cunningham, D. J., and Douglas, C. G., ibid 125:90, 1954. [11] Riley, R. L., Shepard, R. H., Cohn, J. E., Carroll, D. G., and Armstrong, B. W., J. Appl. Physiol. 6:673, 1954. [12] Filley, G. F., Gregoire, F., and Wright, G. W., J. Clin. Invest. 33:517, 1954.

Part III: DURING CO_2 HYPERPNEA

Male subjects at rest. Except where otherwise indicated, measurements are for alveolar CO_2 tension by Haldane-Priestley method. V_D = volume of dead space gas, V_T = tidal volume.

	Air Respiration			Air plus CO_2 Respiration			Reference
	V_T L	V_D L	$\frac{V_D}{V_T} \times 100$ %	V_T L	V_D L	$\frac{V_D}{V_T} \times 100$ %	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	0.532	0.170	32	1.018	0.252	25	1
2	0.468	0.141	30	1.254	0.358	29	1
3	0.400	0.105	26	1.600	0.340	21	2
4	0.500	0.135	27	1.300	0.330	25	2
5		0.142[1]			0.216[1]		3
6					0.385[1]		3
7		0.135[2]			0.109[2]		4
8		0.142[2]			0.143[2]		4

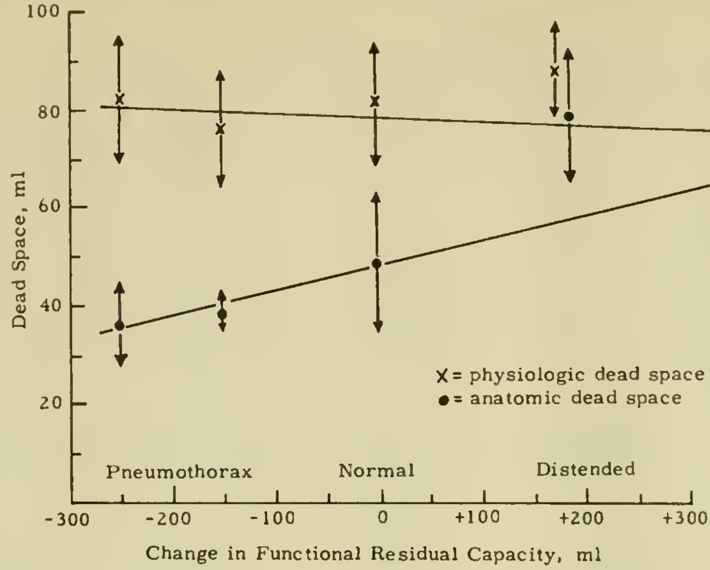
/1/ Arterial CO_2 tension method. /2/ Foreign gas method (hydrogen).

Contributors: (a) Rossier, P. H., (b) Severinghaus, J. W.

References: [1] Campbell, J. M., Douglas, C. G., and Hobson, F. G., J. Physiol. 48:303, 1914. [2] Bannister, R. G., Cunningham, D. J., and Douglas, C. G., ibid 125:90, 1954. [3] Cooper, D. Y., Emmel, G. L., Kough, R. H., and Lambertsen, C. J., Fed. Proc. 12:28, 1953. [4] Siebeck, R., Scand. Arch. Physiol. 25:31, 1911.

48. RESPIRATORY DEAD SPACE AND CHANGE IN FUNCTIONAL RESIDUAL CAPACITY: DOG

Determinations made on 11 dogs; tidal volume was held constant at 200 ml and rate at 10 or 12 respirations per min. Anatomic dead space is proportional to end inspiratory lung volume, while physiologic dead space is approximately constant over range of lung volumes studied. For definitions and clarifying information on various dead space concepts, see Page 46.



Contributor: Severinghaus, J. W.

Reference: Severinghaus, J. W., and Stupfel, M., J. Appl. Physiol. 10:335, 1957.

49. SOME FACTORS AFFECTING RESPIRATORY DEAD SPACE: MAN

Part I: EFFECT OF BREATHHOLDING

Male subjects. V_D = volume of dead space gas. For definitions and clarifying information on various dead space concepts, see Page 46.

	Subjects no.	Dead Space Gas	Quiet Breathing: Inspiration Time sec	Quiet Breathing: V_D ml	Breathholding: Inspiration Time sec	Breathholding: V_D ml	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	2/1/			198	5	157	1
2					10	146	
3				189	5	135	
4					10	118	
5	5/2/		2.0	132	20	70	2
6			2.0	128	21	66	
7			1.3	160	20	95	
8			1.3	173	21	74	
9			2.0	168	22	107	
10			2.5	107	21	55	
11			2.2	114	20	61	
12			2.5	192	22	136	
13			2.1	178	21	145	
14	1/3/	CO_2		195	3	195	3
15					5	160	
16					10	150	
17					20	163	
18					30	138	
19					60	105	
20		He		225	3	175	
21					5	165	
22					10	160	
23					20	132	
24					20	110	
25					60	95	

/1/ Foreign gas method (hydrogen). /2/ Nitrogen method (Lilly nitrogen meter). /3/ Recording mass spectrometer method (Lilly nitrogen meter).

Part I: EFFECT OF BREATHHOLDING (Concluded)

Male subjects. V_D = volume of dead space gas.

	Subjects no.	Dead Space Gas	Quiet Breathing: Inspiration Time sec	Quiet Breathing: V_D ml	Breathholding: Inspiration Time sec	Breathholding: V_D ml	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
26	1[3]	N_2		190	3	170	3
27					5	150	
28					10	140	
29					20	120	
30					30	105	
31					60	118	
32		O_2		210	3	180	
33					5	155	
34					10	140	
35					20	165	
36					30	130	
37					60	115	

/3/ Recording mass spectrometer method (Lilly nitrogen meter).

Contributor: Rossier, P. H.

References: [1] Siebeck, R., Deut. Arch. klin. med. 102:390, 1911. [2] Fowler, W. S., Am. J. Physiol. 154:405, 1948. [3] Bartels, J., Severinghaus, J. W., Forster, R. E., Briscoe, W. A., and Bates, D. V., J. Clin. Invest. 33:41, 1954.

Part II: EFFECT OF BREATHING LEVEL

Each set of values is for a single subject. Unless otherwise indicated, measurements are by foreign gas (H_2) method.

	Sex	Deep Expiratory Level ml	Normal Expiratory Level ml	High Inspiratory Level ml	Reference
	(A)	(B)	(C)	(D)	(E)
1	♂	109	135	152	1
2	♂	109	142	206	
3	♂[1]	33	150	796	2
4	♂	99.5	111	185	3
5	♀	98.5	108.5	171	
6	♂	158		294	4
7	♂[2]	119	168	233	5
8	♀[2]	84	105	202	

/1/ Alveolar CO_2 tension method (Haldane-Priestley). /2/ Nitrogen method.

Contributors: (a) Rossier, P. H., (b) Severinghaus, J. W.

References: [1] Siebeck, R., Scand. Arch. Physiol. 25:91, 1911. [2] Henderson, Y., Chillingworth, F. P., and Whitney, J. L., Am. J. Physiol. 38:1, 1915. [3] Krogh, A., and Lindhard, J., J. Physiol. 51:59, 1917. [4] Mundt, E., Schoedel, W., and Schwarz, H., Pflügers Arch. 244:107, 1941. [5] Fowler, W. S., Am. J. Physiol. 154:405, 1948.

Part III: DEAD SPACE FOR O_2, CO_2, He, AND N_2

Values are for single subjects at rest. All inspirations were 80% He-20% O_2 and followed a period of breathing air. All breathholding times were about $2\frac{1}{2}$ sec. Recording mass spectrometer method (Lilly nitrogen meter). Ranges in parentheses conform to estimate "b" of the 95% range (cf Introduction).

	Sex	O_2 ml	CO_2 ml	He ml	N_2 ml
	(A)	(B)	(C)	(D)	(E)
1	♂	149(141-157)	145(137-153)	141(131-151)	128(122-134)
2	♂	169(151-187)	161(149-173)	152(144-160)	165(159-171)
3	♂	165(155-175)	160(150-170)	155(143-167)	169(163-175)
4	♂	195(185-205)	207(193-221)	198(180-216)	189(179-199)
5	♀	161(145-177)	144(136-152)	134(122-146)	124(114-134)

Contributor: Rossier, P. H.

Reference: Bartels, J., Severinghaus, J. W., Forster, R. E., Briscoe, W. A., and Bates, D. V., J. Clin. Invest. 33:41, 1954.

50. RESPIRATORY DEAD SPACE AND TIDAL VOLUME: MAN

Resting subjects. V_D = volume of dead space gas in ml. V_T = tidal volume in ml. For definitions and clarifying information on various dead space concepts, see Page 46.

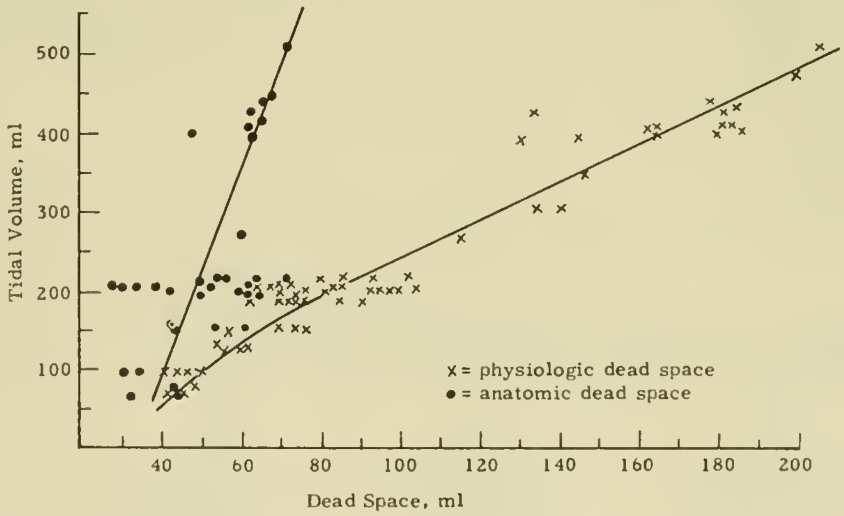
	No. and Sex	Mean Value	Range	Method	Reference
	(A)	(B)	(C)	(D)	(E)
1	1♂	$V_D = 0.31 \times V_T$		Alveolar CO_2 (Haldane-Priestley).	1
2		$V_D = 0.275 \times V_T$		Statistical data.	2
3	50♀	$V_D = 0.4949 \times V_T - 89.9$	$V_D = 0.4949 \times V_T - 30$ $V_D = 0.4949 \times V_T - 160$	Alveolar CO_2 tension (Haldane-Priestley).	3
4	42♂	$V_D = 0.41 \times V_T - 55$	$V_D = 0.41 \times V_T + 30$ $V_D = 0.41 \times V_T - 150$	Alveolar CO_2 tension (Haldane-Priestley).	4
5	1♂	$V_D = 0.24 \times V_T$		Arterial CO_2 tension.	5
6	8♂	$V_D = 0.34 \times V_T$	$V_D = 0.448 \times V_T$ $V_D = 0.186 \times V_T$	Hydrogen clearance.	6
7	4♀	$V_D = 0.254 \times V_T$	$V_D = 0.305 \times V_T$ $V_D = 0.225 \times V_T$	Hydrogen clearance.	6
8	8♂	$V_D = 0.199 \times V_T$	$V_D = 0.29 \times V_T$ $V_D = 0.13 \times V_T$	Arterial CO_2 tension.	7
9	5♂, 3♀	$V_D = 0.30 \times V_T - 4.9$		Nitrogen clearance.	8
10	4♂	$V_D = 0.31 \times V_T$	$V_D = 0.25 \times V_T$ $V_D = 0.38 \times V_T$	Arterial CO_2 tension.	9
11	9♂, 4♀	$V_D = 0.36 \times V_T$	$V_D = 0.36 \times V_T - 25$ $V_D = 0.36 \times V_T + 25$	Arterial CO_2 tension.	10
12	35♂, 15♀	$V_D = 0.35 \times V_T$	$V_D = 0.35 \times V_T - 25$ $V_D = 0.35 \times V_T + 25$	Arterial CO_2 tension.	11

Contributors: (a) Rossier, P. H., (b) Fishman, A. P., (c) Kaltreider, N. L., (d) Severinghaus, J. W.

References: [1] Campbell, J. M., Douglas, C. G., and Hobson, F. G., J. Physiol. 48:303, 1914. [2] Enghoff, H., Scand. Arch. Physiol. 63:15, 1931. [3] Hurtado, A., Fray, W. W., Kaltreider, N. L., and Brooks, W. D., J. Clin. Invest. 13:169, 1934. [4] Kaltreider, N. L., Fray, W. W., and Hyde, H. van Z., Am. Rev. Tuberc. 37:662, 1938. [5] Enghoff, H., Upsala läk. fören. förh. 44:191, 1938. [6] Birath, G., Acta med. scand. suppl., 154, 1944. [7] Riley, R. L., and Cournand, A., J. Appl. Physiol. 1:825, 1949. [8] Bateman, J. B., ibid 3:143, 1950. [9] De Coster, A., and Denolin, H., Acta clin. belg. 9:135, 1954. [10] Bartels, H., Beer, R., Koepchen, H. P., Wenner, J., and Witt, I., Pflügers Arch. 261:133, 1955. [11] Rossier, P. H., and Buhlmann, A., unpublished.

51. RESPIRATORY DEAD SPACE AND TIDAL VOLUME: DOG

Male subjects. V_D = volume of dead space gas. For definitions and clarifying information on various dead space concepts, see Page 46.



Contributor: Severinghaus, J. W.

Reference: Severinghaus, J. W., and Stupfel, M., J. Appl. Physiol. 10:335, 1957.

52. RESPIRATORY DEAD SPACE IN PATHOLOGICAL CONDITIONS: MAN

Ranges are estimate "c" of the 95% range (cf Introduction). V_D = volume of dead space gas, V_T = tidal volume. For definitions and clarifying information on various dead space concepts, see Page 46.

	Condition	Subjects no.	Sex	V_D ml	$\frac{V_D}{V_T} \times 100$ %	Method	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Emphysema	8	♂	189-253		Foreign gas (hydrogen)	1
2		2	♂	490-570	59-76	Hydrogen clearance	2
3		6	♂		23-52	Arterial CO_2 tension	3
4		5	♂		35-53	Arterial CO_2 tension	4
5		5	♂	142-231	36-47	Arterial CO_2 tension	5
6		100		190-320	38-60	Arterial CO_2 tension	6
7	Sarcoidosis	22	♂		11-48	Arterial CO_2 tension	7
8	Pulmonary fibrosis, including sarcoidosis	8		190-310	36-60	Arterial CO_2 tension	6
9	Pneumonectomy, recently operated	15		120-160	47[1]	Arterial CO_2 tension	8
10		5	♂	160-340	36-57	Hydrogen clearance	2
11		1	♀	300	50	Hydrogen clearance	2
12	Pneumonectomy with thoracoplasty	15		80-120	26[1]	Arterial CO_2 tension	8
13	Pneumothorax, unilateral	9	♂	190-450	38-60	Hydrogen clearance	2
14		2	♀	90-140	29	Hydrogen clearance	2
15	Pneumothorax, bilateral	2	♂	180-270	35-59	Hydrogen clearance	2
16	Thoracoplasty	8	♂	140-400	44-57	Hydrogen clearance	2
17		2	♀	150-190	37-39	Hydrogen clearance	2
18	Renal and diabetic acidosis	5		To 400		Arterial CO_2 tension	6
	Acute asthmatic attacks						
19	Before attack	5	♂	190-320	28-44	Arterial CO_2 tension	9
20	During attack	5	♂	254-686	40-65	Arterial CO_2 tension	9
21	Before attack	3	♀	230-310	37-51	Arterial CO_2 tension	9
22	During attack	3	♀	167-294	42-63	Arterial CO_2 tension	9

/1/ Mean value.

Contributors: (a) Rossier, P. H., (b) Severinghaus, J. W.

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D_x is the amount of gas in ml (STPD) per min which diffuses through the whole lung, when a mean partial pressure difference of one mm Hg exists between alveolar air and capillary blood of the lung ($\Delta \bar{p}$). $D = \frac{\text{ml gas}}{\text{min} \times \Delta \bar{p}}$; therefore, the total oxygen consumption of the lungs (Q) is as follows: $Q = D_{O_2} \times \Delta \bar{p}$. Calculation of D_{O_2} from D_{CO}: $D_{O_2} = D_{CO} \times 1.23$. Calculation of D_{CO_2} from D_{CO}: $D_{CO_2} = D_{CO} \times 24.6$. Methods: A = single breath CO method of Krogh [1], or modification [2]; B = oxygen method with graphical integration of mean oxygen pressure gradient [3]; C = steady state CO method based on arterial CO_2 tension; D = steady state CO method based on end tidal gas sampling or assumed dead space value; E = radioactive C^{140} method of Kruhoffer. Values are in most cases corrected for lung volume at mid-capacity (sum of residual reserve and half the resting tidal volume) or for the volume at functional residual capacity (sum of residual and reserve volume). Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

Part I: AT REST AND DURING ACTIVITY

	Age	No. and Sex	Method	D_{O_2} Rest	D_{O_2} Work	Work Load	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	10-15 yr	5, ♂♀	A	23.1(20.6-27.3)			1
2	Adult	14♂	A	36.7(27.8-43.3)			1
3		5♀	A	28.0(21.9-30.5)			1,4
4		10♂	E	27(21-31)[1]			5
5		5♀	E	22(20-24)[1]			5
6		9♂	B	24.4(16-36)[2]			6
7	25-28 yr	5♂	A		51.3(41.7-60.2)	450 kg-m/min	4
8		6♂	A	35.6(24.7-42.9)	55.7(43.0-68.8)	670-900 kg-m/min	4
9		5♂	A		63.5(60.4-66.8)	1130 kg-m/min	4
10		4♂	A		57.5(49.0-68.6)	1300 kg-m/min	4
11		3♂	A		63.7(57.3-73.4)	1590 kg-m/min	4
12	Adult	6♂	B	21(12-36)[3]	62(50-76)[2]		7
13		6♂, 1♀	C	20.7(12.9-34.5)	44.6(28.5-67.6)[4]	2-16% grade at 2.5-3.5 mi/hr	8
14		14♂, 4♀	D	21.6(13.0-35.3)	37.9(25.5-53.4)	0 grade at 3 mi/hr	9
15		12, ♂♀	D		39.2(29.6-57.8)	9% grade at 3 mi/hr	9

/1/ 15% O_2 in inspired air. /2/ 12% O_2 in inspired air. /3/ 10% O_2 in inspired air. /4/ 10 males, 1 female.

Contributors: (a) Bartels, H., and Opitz, E., (b) Bates, D. V.

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Part II: EFFECT OF ACCLIMATIZATION TO ALTITUDE

	No. and Sex	Method	D_{O_2} Sea Level	D_{O_2} Acclimatized	D_{O_2} Residents	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	5♂	A	35.2(25.3-46.8)	36.5(25.4-43.8)[1]	48.0(41.5-65.3)[1]	1
2	6♂	B	(20-30)	70[2, 3]		2

/1/ Altitude 13,000 feet at Cerro di Pasco, Peru. /2/ At 20,000 feet after 22 days in low-pressure chamber following gradual ascent. /3/ One subject.

Contributors: Bartels, H., and Opitz, E.

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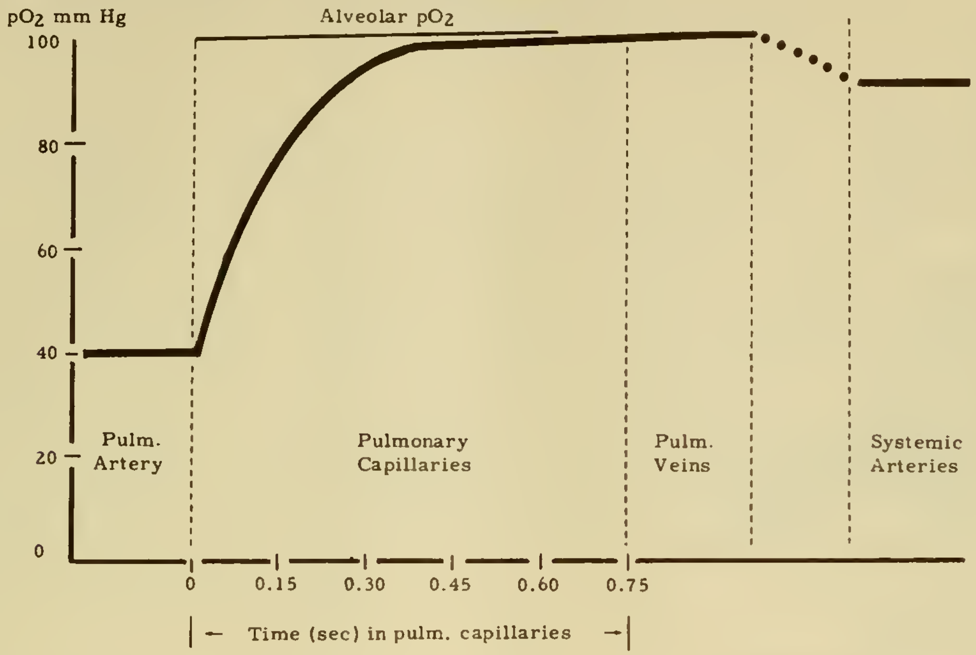
54. ALVEOLAR-CAPILLARY DIFFUSION: MAN

Part I: PULMONARY CAPILLARY O_2 PRESSURE

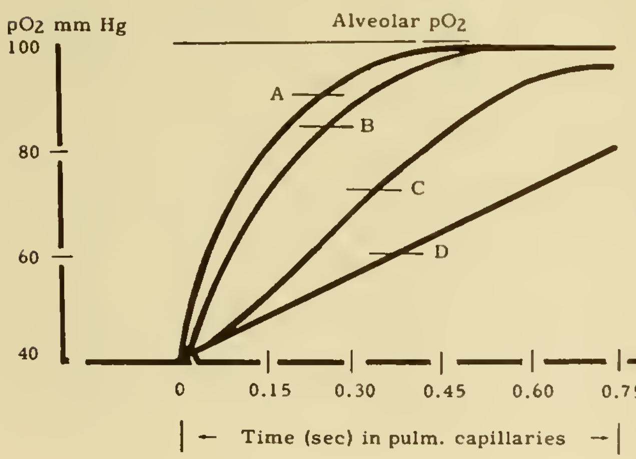
Mixed venous blood enters the pulmonary capillaries with pO_2 of 40 mm Hg. Blood normally requires about 0.75 seconds to pass through the capillaries, at the end of which time its pO_2 has risen to almost 100 mm Hg. The pO_2 of arterial blood is lower because of venous-to-arterial shunts.



Reference: Comroe, J. H., Jr., Forster, R. E., II, DuBois, A. B., Briscoe, W. A., and Carlsen, E., "The Lung," Chicago: The Year Book Publishers, Inc., 1956.

Part II: END- AND MEAN CAPILLARY O_2 PRESSURE

The graphic and tabular presentation illustrates different rates at which venous blood may be oxygenated in pulmonary capillaries, depending upon the diffusing capacity of the lung. Alveolar pO_2 in each case is 100 mm Hg.



	Diffusing Capacity for O_2	End-capillary pO_2		Mean Capillary pO_2	
		Gradient	mm Hg	Gradient	mm Hg
A	27.7	<0.01	99.99	9	91
B	16.6	<0.1	99.9	15	85
C	9.1	4.0	96.0	27.5	72.5
D	6.4	18.6	81.4	39	61

Reference: Comroe, J. H., Jr., Forster, R. E., II, DuBois, A. B., Briscoe, W. A., and Carlsen, E., "The Lung," Chicago: The Year Book Publishers, Inc., 1956.

	Condition	Pressure, mm Hg[1]				Blood Flow L/min	Reference
		Arterial			Venous[2]		
		Systolic	Diastolic	Mean			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Man						
1	Resting[3]	25	14	18		6.0	1
2	Resting[3]			14		7.1	2
3	Resting[3]	25	11	16		5.4	3
4	Resting	23	9	15	9	7.4	4
5	Resting			16	7	5.5	5
6	Exercise, supine[3]			15		10.4	2
7	Exercise, supine			21	10	9.6	6
8	Exercise, standing[3]	26	9	16		12.0	1
9	Hypoxia			20	7	5.5	5
10	Hypoxia[3]	26	12	18	8	8.0	7
11	Saline infusion[3]			23	16	6.7	8
	Drug effect, intravenous						
12	Epinephrine[3]			19	7	7.9	9
13	Norepinephrine	28	11	21	15	4.5	10
14	Tetraethylammonium chloride			15	10	4.7	11
	Disease patterns						
15	Emphysema, mild[3]	29	12	18		5.5	12
16	Emphysema, severe[3]	43	16	28		5.6	12
17	Cor pulmonale, with hypoxia[3]	43	19	28		5.4	12
18	Cor pulmonale, with hypoxia			35	9	5.4	13
19	Cor pulmonale, with congestive failure[3]	74	39	52		7.4	12
20	Primary pulmonary hypertension[3]	101	47	66		2.9	14
21	Left ventricular failure			45	30	3.5	4
22	Mitral stenosis			51	29	4.3	15
23	Mitral stenosis	68	33	47	28	4.0	16
24	Mitral insufficiency			15	12	5.9	17
25	Mitral stenosis and insufficiency			36	23	3.8	17
26	Aortic stenosis and insufficiency			29	16	5.0	18
27	Chronic constrictive pericarditis	36	22	26	20	4.3	19
	Atrial septal defect						
28	Left to right shunts[3]	38	12	23	13[4]	16.5	20
29	Left to right shunts[3]	31	14	21	8	18.0	4
	Atrial septal defect						
30	Right to left shunts[3]	96	53	68	9[4]	2.6	20
31	Right to left shunts[3]	88	59	73		3.5	21
32	Patent ductus arteriosus	43	19	29		12.2	22
33	Patent ductus arteriosus	34	17	28	14	19.0	4
34	Patent ductus arteriosus[3]	46	23	31		7.7	23
35	Patent ductus arteriosus[3]			36		12.4	24
36	Tetralogy of Fallot		8	4	6	2.5	25
37	Pulmonic stenosis	24	10	17	11	5.4	a
38	Eisenmenger syndrome	120	65	87	8	3.3	4
39	Eisenmenger syndrome			86		3.5	a
40	Ventricular septal defect[3]			37		10.3	24
41	Ventricular septal defect	35	20	27		5.7	a
	Dog						
42	Resting[5]			18	10	2.3	26
43	Resting			17	4	3.2	27
44	Hypoxia, moderate[5]			22	8[4]	2.4	26
45	Hypoxia, moderate			26	4[4]	3.8	27
46	Hypoxia, severe			26	9[4]	8.1	26

/1/ Zero point = 10 cm anterior to back in man; zero point = back in dog. /2/ Pulmonary "capillary" mean pressure used except where indicated. /3/ Pressure approximately corrected to 10 cm zero point. /4/ Pulmonary venous or left atrial mean pressure. /5/ Anesthetized.

Contributor: (a) Gorlin, R.

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56. BLOOD GASES, VARIABLES, FACTORS, AND CONSTANTS: MAN

The values from which this table has been synthesized are in many instances derived by calculation from basic assumptions, factors, and constants, and do not have the same validity as measured values. Those for females are in general less well-founded than those for males. A = arterial blood, V = mixed venous blood.

	Variable	Blood	Sex	Whole Blood: ml Gas in 100 ml Whole Blood	Whole Blood: ml Gas in ♂ 45.0 ml ♀ 40.0 ml RBC	Whole Blood: ml Gas in ♂ 55.0 ml ♀ 60.0 ml Plasma	ml Gas in 100 ml RBC (In Contact)[1]	ml Gas in 100 ml Plasma (In Contact)[1]	Blood Gas Pressure (Tension) mm Hg	Factors and Constants	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
1	Oxygen capacity[2]		♂	20.4			45.3				
2			♀	18.0			45.3[3]				
											A-V O_2 Diff.
3	Total oxygen	A	♂	20.3	20.1	0.142	44.7	0.258	94		5.00
4			♀	17.9	17.7	0.155	44.7	0.258	94[3]		4.20
5		V	♂	15.3	15.2	0.060	33.9	0.110	40		
6			♀	13.7	13.6	0.068	34.4	0.113	41		
										αO_2 Cells[4]	αO_2 Plasma[4]
7	Free oxygen	A	♂	0.285	0.144	0.142	0.319	0.258	94		
8			♀	0.282	0.126	0.156	0.319	0.258	94[3]	0.0258	0.02089
9		V	♂	0.122	0.061	0.061	0.136	0.110	40		
10			♀	0.124	0.055	0.068	0.139	0.113	41		
										HbO_2 Sat. %	
11	Combined oxygen (HbO_2)	A	♂	20.0	20.0	0	44.4	0	94	98	
12			♀	17.6	17.6	0	44.4	0	94[3]	98	
13		V	♂	15.2	15.2	0	33.6	0	40	73.5	
14			♀	13.6	13.6	0	34.3	0	41	74.5	
										"f"[5]	A-V CO_2 Diff.[6]
15	Total carbon-dioxide	A	♂	49.0	16.2	32.8	36.0	59.6	41	1.217	4.1
16			♀	48.0	13.6	34.4	34.3	57.0	39	1.187	3.4
17		V	♂	53.1	18.0	35.1	40.1	63.8	46	1.201	
18			♀	51.4	14.9	36.5	37.7	60.4	43	1.175	
										αCO_2 Cells[7]	αCO_2 Plasma[7]
19	Free carbon-dioxide	A	♂	2.62	1.06	1.56	2.36	2.84	41		
20			♀	2.53	0.89	1.64	2.25	2.72	39	0.4399	0.5311
21		V	♂	3.00	1.21	1.79	2.69	3.25	46.5		
22			♀	2.78	0.96	1.82	2.44	3.01	43		
										pH Cells	pH Plasma
23	Total combined carbon-dioxide	A	♂	46.4	15.1	31.2	33.6	56.8	41	7.19	7.40
24			♀	45.5	12.7	32.8	32.1	54.3	39	7.20	7.40
25		V	♂	50.1	16.8	33.3	37.4	60.5	46.5	7.17	7.37
26			♀	48.6	14.0	34.7	35.3	57.4	43	7.18	7.38
										"c" Cells[8]	"c" Plasma[8]
27	Carbamino carbon-dioxide	A	♂	2.2	1.7	0.4	3.9	0.8	41	0.115	0.014
28			♀	1.9	1.5	0.5	3.7	0.8	39	0.116	0.014
29		V	♂	3.1	2.6	0.5	5.8	0.8	46.5	0.154	0.014
30			♀	2.7	2.2	0.5	5.5	0.8	43	0.156	0.014
31	Bicarbonate carbon-dioxide	A	♂	44.2	13.4	30.8	29.8	56.0	41		
32			♀	43.6	11.2	32.3	28.3	53.5	39		
33		V	♂	47.0	14.2	32.8	31.6	59.7	46.5		
34			♀	46.0	11.8	34.2	29.8	56.6	43		
										αN_2 Cells[9]	αN_2 Plasma[9]
35	Nitrogen	A, V	♂	0.979	0.494	0.484	1.099	0.881	572	0.0146	0.0117
36			♀	0.970	0.437	0.534	1.103	0.884	574		

/1/ 100 ml RBC in contact with plasma, and 100 ml plasma in contact with RBC. /2/ O_2 capacity = g Hb x 1.36. This factor based on hemoglobin Fe content of 0.339%. /3/ Assumed to be equal to the value for males. /4/ ml O_2 dissolved in 100 ml human RBC = 100 x 0.0258 x O_2 pressure/760; ml O_2 dissolved in 100 ml horse plasma = 100 x 0.02089 x O_2 pressure/760. /5/ Plasma CO_2 = "f" x blood CO_2; "f" depends upon pH, O_2 capacity, and HbO_2 saturation per cent. /6/ Arterio-venous CO_2 difference calculated as A-V O_2 difference x standard resting respiratory quotient of 0.82. /7/ ml CO_2 (including H_2CO_3) dissolved in 100 ml RBC = 0.4399 x 100 x CO_2 pressure/760. For plasma, substitute 0.5311 instead of 0.4399. /8/ The values of the factor "c" are provisional, as other factors underlying it have not in every instance been determined for human blood. Combined CO_2 x "c" = carbamino CO_2 in 100 ml of red blood corpuscles or plasma. For cells, "c" is calculated from $K'/K_{carbamino}$ (= 0.315 for HbO_2, 0.11 for reduced Hb) and the mEq of Hb (= 2.05 x 20.0 mM Hb for male arterial cells, 2.08 x 20.0 for female arterial cells, 1.99 x 14.7 and 1.55 x 5.3 for male venous cells, 2.02 x 14.9 and 1.57 x 5.1 for female venous cells), and for plasma, "c" is calculated from $K'/K_{carbamino}$ (= 1.2) and the mEq of plasma proteinate (= 17.0). /9/ ml N_2 dissolved in 100 ml RBC = 0.0146 x 100 x N_2 pressure/760. For plasma, substitute 0.0117 for 0.0146.

Contributors: (a) Barron, D. H., (b) Bing, R. J., (c) Comroe, J. H., Jr. (d) Cournand, A., (e) Drabkin, D. L., (f) Hickam, J. B., (g) Kirk, J. E., (h) Lambertsen, C. J., and Kough, R. H., (i) Otis, A. B., (j) Penrod, K. E., (k) Singer, R. B., (l) Singer, R. B., and Hastings, A. B., (m) Van Slyke, D. D., (n) Wood, E.

Reference: Albritton, E. C., "Standard Values in Blood," Philadelphia: W. B. Saunders Co., 1952 (adapted from Table 94).

57. ARTERIAL AND VENOUS BLOOD GAS COMPARISONS: MAN, ADULT AND NEWBORN

In the adult, A = arterial blood from femoral or brachial artery; V = venous blood from internal jugular vein, unless otherwise indicated; all values for males, under resting conditions. In the newborn (before first breath), where the oxygenated blood goes from the placenta to the fetus via the umbilical vein, A = arterial blood from vena umbilicalis, V = venous blood from arteria umbilicalis. Methods: A-R = calculated from alkali reserve, Henderson nomogram, and CO_2 content; D-M = potentiometric measurement with the dropping-mercury electrode; G-E = measurement with glass electrode; H-H = calculated from the Henderson-Hasselbalch equation, using 6.10 for pK'; P-A = calculated from pH and arterial CO_2 content converted to plasma CO_2 content by use of the Henderson-Hasselbalch equation; R-C = Van Slyke-Neill manometric method with Roughton corrections for O_2 capacity; V-N = Van Slyke-Neill manometric method. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Measurement	Blood	Adult			Newborn			Reference
			Subjects no.	Method	Value	Subjects no.	Method	Value	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	O_2 pressure,	A	59	D-M	93.0(80.0-104.0)	50	D-M	24.4(13.5-34.0)	C-E, 1;F-H, 2
2	mm Hg	V[1]	9	D-M	39.4(29.5-48.5)	47	D-M	10.4(1.2-19.0)	C-E, 3;F-H, 2
3	O_2 content,	A	50	V-N	19.6(17.3-22.3)	24	V-N	10.6(5.6-17.9)	C-E, 4;F-H, 2
4	vol %	V	50	V-N	12.9(11.0-16.1)	19	V-N	2.9(0.4-8.4)	C-E, 4;F-H, 2
5	O_2 capacity,	A	46	R-C	20.2(16.8-22.9)	24	V-N	22.2(17.2-26.2)	C-E, 5;F-H, 2
6	vol %	V[1]	9	V-N	4.2(3.2-5.8)[2]	18	V-N	7.2(2.1-12.5)[2]	C-E, 3;F-H, 2
7	O_2 satura-	A	46	R-C	96.2(93.5-97.5)	24	V-N	47.7(25.7-73.8)	C-E, 5;F-H, 2
8	tion, %	V	50	V-N	61.8(55.3-70.7)	18	V-N	13.9(2.4-37.6)	C-E, 4;F-H, 2
9	CO_2 pres-	A	50	P-A	39.9(36.2-44.9)	11	A-R	44.9(35.0-60.0)	C-E, 4;F-H, 2
10	sure, mmHg	V	50	P-A	49.9(46.9-54.3)	9	A-R	59.2(43.5-68.0)	C-E, 4;F-H, 2
11	CO_2 content,	A	50	V-N	48.2(44.6-50.2)	23	V-N	40.9(31.2-51.8)	C-E, 4;F-H, 2
12	vol %	V	50	V-N	54.8(51.0-57.7)	19	V-N	48.0(37.4-55.2)	C-E, 4;F-H, 2
13	pH	A	50	G-E	7.424(7.374-7.455)	11	H-H	7.32(7.23-7.41)	C-E, 4;F-H, 2
14		V	50	G-E	7.37(7.32-7.40)	9	H-H	7.25(7.14-7.37)	C-E, 4;F-H, 2

/1/ Mixed venous blood from pulmonary artery. /2/ Arterio-venous O_2 difference.

Contributors: Bartels, H., and Opitz, E.

References: [1] Bartels, H., and Rodewald, G., Pflügers Arch. 256:113, 1952. [2] Beer, R., Bartels, H., and Raczkowski, H. A., ibid 260:306, 1955. [3] Bartels, H., Beer, R., Fleischer, E., Hoffheinz, H. J., Krall, J., Rodewald, G., Wenner, J., and Witt, I., ibid 261:99, 1955. [4] Gibbs, E. L., Lennox, W. G., Nims, L. F., and Gibbs, F. A., J. Biol. Chem. 144:325, 1942. [5] Douglas, J. C., and Edholm, O. G., J. Appl. Physiol. 2:307, 1949.

Single observation on each subject, unless otherwise specified. All blood gases measured by manometric method of Van Slyke and Niell [1], with the exception of Line 6, Column D (measured by method of Roughton and Scholander [2]). Values in parentheses are ranges, estimate "c" of the 95% range, unless otherwise specified (cf Introduction).

	Animal	Subjects no.	Physiologic State	A-V O_2 vol %	V-A CO_2 vol %	Metabolic Rate ml O_2/min	Blood Flow ml/100 g/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
				Systemic[1]				
1	Man	24[2]	Rest	4.4 (3.0-5.8)b				3
2		6[3]	Rest	3.9				3
3		3	Rest, control	3.8 (3.6-4.2)		126 (111-147)		4
4		3	Exercise, mild[4]	7.3 (6.2-7.6)		406 (269-512)		4
5		3	Exercise, mild[4]	10.2 (9.2-11.6)		812 (700-912)		4
6	Dog	20	Pentothal, light	4.2 (3.4-5.0)b	4.1 (3.7-4.5)b[5]			5
7		9	Pentobarbital	4.1 (2.3-6.3)				6
				Cerebral[6]				
8	Man	14[7]	Rest, normal	6.3 (3.9-8.7)b	6.4	3.3 (2.4-4.2)b	54 (36-72)b[8]	7
9		8	Pentothal seminarcosis	6.2 (5.6-7.0)	6.1 (5.0-7.1)	Normal	Normal[8]	8
10	Monkey	11	Pentobarbital	8.0 (6.0-10.1)	8.0 (6.0-10.7)	3.7 (2.5-4.5)	47 (33-74)[8]	9
11	Dog	5	Pentobarbital	9.1 (5.3-15.1)				10
				Coronary[9]				
12	Dog	20	Pentothal	13.1 (12.0-14.2)b	12.6 (11.2-14.0)			5
13		9	Pentobarbital	13.4 (12.1-15.8)		8.0 (5.6-14.4)	60 (45-107)[10]	6

/1/ Venous samples: Lines 1 and 2, right auricle or ventricle via catheter; Lines 3-7, pulmonary artery via catheter. Arterial samples: all from brachial or femoral artery. /2/ Thirteen normal males and 11 male patients with normal cardiovascular function. /3/ Female patients with normal cardiovascular function. /4/ Intensity of exercise indicated by corresponding metabolic rates. /5/ Represents only 10 observations. /6/ Venous samples: Lines 8 and 9, jugular bulb via needle puncture; Line 10, cannulation of both internal jugulars; Line 11, sagittal sinus via cannula. /7/ Thirty-four observations. /8/ Measured by method of Kety and Schmidt [11]. /9/ Venous samples: Lines 12 and 13, catheterization of coronary sinus. /10/ Measured by an adaptation of the nitrous oxide method of Kety and Schmidt [11].

Contributor: Hegnauer, A. H.

References: [1] Van Slyke, D. D., and Niell, J. M., J. Biol. Chem. 61:523, 1924. [2] Roughton, F. J., and Scholander, P. F., ibid 148:541, 1943. [3] Cournand, A., Riley, R. L., Breed, E. S., Baldwin, E. de F., and Richards, D. W., Jr., J. Clin. Invest. 24:106, 1945. [4] Riley, R. L., Himmelstein, A., Motley, H. L., Weiner, H. M., and Cournand, A., Am. J. Physiol. 152:372, 1948. [5] Goodale, W. T., Lubin, M., Eckenhoff, J. E., Hafkenschiel, J. H., and Banfield, W. G., Jr., ibid 152:340, 1948. [6] Eckenhoff, J. E., Hafkenschiel, J. H., Foltz, E. L., and Driver, R. L., ibid 152:545, 1948. [7] Kety, S. S., and Schmidt, C. F., J. Clin. Invest. 27:476, 1948. [8] Kety, S. S., Woodford, R. B., Harmel, M. H., Freyhan, F. A., Appel, K. E., and Schmidt, C. F., Am. J. Psychiat. 104:765, 1947-48. [9] Schmidt, C. F., Kety, S. S., and Pennes, H. H., Am. J. Physiol. 143:33, 1945. [10] Lougheed, W. M., and Kahn, D. S., J. Neurosurg. 12:226, 1955. [11] Kety, S. S., and Schmidt, C. F., Am. J. Physiol. 143:53, 1945.

59. ARTERIO-VENOUS LACTATE AND PYRUVATE DIFFERENCES IN VARIOUS STRUCTURES: MAN

Methods: C = colorimetric, highly specific, greatly delayed collection technique [1]; D = distillation, relatively high (non-specific), delayed collection technique [2,3]; E = colorimetric, extremely rapid collection [1,4]; F = colorimetric, fairly rapid collection [1,5]; M = colorimetric, not arterio-venous but arm vein minus hepatic vein, directional value only [1,6]; R = fairly specific, extremely rapid collection; S = specific, moderately rapid collection [5,6]; U = unknown collection technique, analysis completely specific (chromatographic); Y = very specific, extremely rapid collection [4]. All values taken in state of complete rest. Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Structure	Lactate mM/L	Lactate Method	Pyruvate mM/L	Pyruvate Method	Lactate-Pyruvate Ratio	Lactate-Pyruvate Method	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
				Concentrations				
1	Artery	1.100	D					7
2		0.887	C					8
3		0.667	F					9
4		0.670	F					5
5		0.618(0.464-0.772)	E	0.142(0.044-0.240)	Y	4.24(3.36-5.12)	E, Y	10
6				0.144	S			11
7	Vein, arm	1.110	D					12
8		1.450	D					13
9		1.540	D					14
10		1.222(0.514-1.930)	F	0.119(0.021-0.217)	S	10.12(8.18-12.06)	F, S	10
11		1.130	D	0.088	S	13.20	D, S	15
12				0.116	R	9.30	R	16
13				0.073(0.041-0.105)	U			17
14						11.3	D, S	15
				A-V Differences[1]				
15	Forearm	-0.110(-0.154 to -0.066)	F					18
16		-0.164(-0.238 to -0.090)	E	-0.025(-0.139 to +0.089)	Y	-0.44(-0.74 to -0.14)	E, Y	19
17	Leg	-0.237(-0.405 to -0.069)	E	-0.030(-0.158 to +0.098)	Y	-0.49(-1.01 to +0.03)	E, Y	19
18	Brain	-0.178(-0.288 to -0.068)	D	-0.025(-0.063 to +0.013)	S			7
19	Heart	+0.300	F	+0.045	S			20
20		+0.574(-0.406 to +1.554)	E	+0.054(-0.020 to +0.128)	Y	+0.54(+0.32 to +0.76)	E, Y	19
21	Splanchnic	-0.280	M	+0.050	M	-6.51	M	21
22	Uterus, pregnant	+0.350	E	+0.072	Y	+2.40	E, Y	19

/1/ Venous concentration algebraically subtracted from arterial concentration, i.e., negative values indicate output by the various structures.

Contributor: Huckabee, W. E.

References: [1] Barker, S. B., and Summerson, W. H., J. Biol. Chem. 138:535, 1941. [2] Edwards, H. T., ibid 125:571, 1938. [3] Friedemann, T. E., Cotonio, M., and Shaffer, P. A., ibid 73:335, 1927. [4] Huckabee, W. E., J. Appl. Physiol. 2:163, 1956. [5] Friedemann, T. E., and Haugen, G. E., J. Biol. Chem. 144:67, 1942. [6] Friedemann, T. E., and Haugen, G. E., ibid 147:415, 1943. [7] Gibbs, E. L., Lennox, W. G., Nimms, L. F., and Gibbs, F. A., ibid 144:325, 1942. [8] Bay, E., Barron, E. S., Adams, W., Gase, T., Halstead, W. C., Ricketts, H. T., Committee on Medical Research, Office of Scientific Research and Development, Rept. No. 344, 1944. [9] Decker, D. G., and Rosenbaum, J. D., Am. J. Physiol. 138:7, 1942. [10] Huckabee, W. E., J. Clin. Invest. 37:255, 1958. [11] Himwich, W. A., and Himwich, H. E., J. Neurophysiol. 9:133, 1946. [12] Bock, A. V., Dill, D. B., and Edwards, H. T., J. Clin. Invest. 11:775, 1932. [13] Weiss, S., and Ellis, L. B., Arch. Int. M. 55:665, 1935. [14] Hallock, P., J. Clin. Invest. 18:385, 1939. [15] Friedemann, T. E., Haugen, G. E., and Kmieciak, T. C., J. Biol. Chem. 157:673, 1945. [16] Bueding, E., and Goldfarb, W. J., ibid 141:539, 1940. [17] Seligson, D., McCormick, G. J., and Sborov, V., J. Clin. Invest. 31:661, 1952. [18] Andres, R., Cader, G., and Zierler, K. L., ibid 35:671, 1956. [19] Huckabee, W. E., unpublished. [20] Goodale, W. T., Olson, R. E., and Hackel, D. B., Fed. Proc. 9:49, 1950. [21] Mendeloff, A. I., J. Clin. Invest. 33:1298, 1954.

60. ARTERIO-VENOUS POSTABSORPTIVE GLUCOSE DIFFERENCES: MAN

Values are mg/100 ml. Those in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Observations	Arterial Blood	Venous Blood	A-V Difference	Reference
	(A)	(B)	(C)	(D)	(E)
1	100[1]	88.4(78-97)[2]	83.9(74-95)	4.5(1-13)	1
2	63	91.5(72-121)[4]	89.0(67-121)	2.5(0-4)	2
3	10[3]	85.0(68-108)[4]	77.0(66-89)	9.0(-1 to +34)	2
4	16[5]	99.0(93-105)[4]	98.0(87-105)	1.0(-2 to +7)	3

/1/ Copper iodometric analysis on zinc sulfate-barium hydroxide filtrate; anticoagulant = potassium oxalate-sodium fluoride; accuracy = 1 mg/100 ml. /2/ Finger-tip blood, demonstrated to be arterial in character. /3/ Analytical method and accuracy not stated. /4/ Radial artery. /5/ Analytical method of Folin and Wu (1920).

Contributor: Hegnauer, A. H.

References: [1] Somogyi, M., J. Biol. Chem. 174:189, 1948. [2] Rabinowitch, I. M., Brit. J. Exp. Path. 8:76, 1927. [3] Foster, G. L., J. Biol. Chem. 55:291, 1923.

61. BLOOD LACTATE VENOUS LEVELS IN CONDITIONS OF REST, EXERCISE, AND HYPERVENTILATION: MAN

Data, except for Lines 4 and 7, were obtained on tungstic-acid filtrate via $KMnO_4$ oxidation to aldehyde, and titration of bound aldehyde by iodine. Data for Line 4: through conversion to aldehyde by concentrated H_2SO_4, and color formation with para-phenyl phenol. Data for Line 7: by oxidation with $KMnO_4$ and measured as CO_2 manometrically in Van Slyke apparatus. Values are expressed in mg/100 ml. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Observations	Rest[1]	Exercise	Hyperventilation	Altitude[2]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	26[3]	12.0(8.4-16.6)				1
2	11[4]	11.7(9.0-16.0)	12.6(8.6-25.4)[5]			2
3	6	12.5(10.0-16.9)	17.8(11.8-22.0)[6]			1
4	6	19.0(5.0-45.0)	77.0(53.0-86.0)[7]			3
5	1	10.7	38.7[8]			4
6	1	10.7	139.5[9]			4
7	6	13.2(5.2-21.6)	157.0(145.0-174.0)[10]			5
8	6	10.1(8.1-13.6)		27.6(21.3-35.7)[11]		2
9	1	8.2			16.2[12]	4

/1/ At sea level. /2/ At 22,000 ft. /3/ On 9 subjects on different days; day-to-day variations may reach ± 25% of mean. /4/ On 3 subjects in good physical condition, walking 3.5-8.6 mph. /5/ Only the subject walking at 8.6 mph showed rise in blood lactate (to 25.4 mg%). /6/ Increases in 3 subjects, walking 4.5-5.25 mph. /7/ Severity of exercise not stated. /8/ Jogging at 6.48 mph. /9/ Running at 8.8 mph. /10/ Samples taken 4-10 min after 440-yd run by untrained subjects. Samples at 1-2 min show only 124 mg%, indicating that following strenuous exercise blood lactate continues to rise for 3-6 min. /11/ Hyperventilation to alveolar pCO_2 of 11-15 mm Hg. /12/ Simulated altitude reached without supplementary O_2 in 1 hr (no acclimatization); approximately linear rise in blood lactate starting at 10,000 ft.

Contributor: Hegnauer, A. H.

References: [1] Cook, L. C., and Hurst, R. H., J. Biol. Chem. 79:443, 1933. [2] Bock, A. V., Dill, D. B., and Edwards, H. T., J. Clin. Invest. 11:775, 1932. [3] Hummel, J. P., J. Biol. Chem. 180:1225, 1945. [4] Friedemann, T. E., Haugen, G. E., and Kmieciak, T. C., ibid 157:673, 1945. [5] Laug, E. P., Am. J. Physiol. 107:687, 1934.

62. ARTERIO-VENOUS LACTATE DIFFERENCES IN CONDITIONS OF REST, EXERCISE, AND HYPERVENTILATION: MAN

Values are expressed in mg/100 ml. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Observations	Arterial Blood	Venous Blood	A-V Difference[1]	Reference
	(A)	(B)	(C)	(D)	(E)
			Rest[2]		
1	7	12.6(9.7-16.3)[3]	12.5(9.0-14.7)[4]	0	1
2	6	14.1(11.7-16.2)[3]	14.4(10.2-18.0)[5]	0	1
			Exercise[6]		
3	2[7]	65.2(58.6-71.8)[3]	68.5(62.1-74.8)[4]	-3.3	1
4	1[8]	75.8[3]	74.8[4]	0[9]	1
			Hyperventilation[10]		
5	6	21.5(11.9-27.7)[11]	27.6(21.3-35.7)[12]	-6.1(0 to -15.7)	2

/1/ A-V differences given as zero unless statistically significant, or greater than analytical error. /2/ Day-to-day variations in resting venous level may range from 7-25% of mean. /3/ Femoral artery. /4/ Femoral vein. /5/ Jugular bulb. /6/ Standing-running at full speed for 1 min. /7/ Blood samples taken within 3 min after exercise. /8/ Blood samples taken 5 min after exercise. /9/ 1 mg difference may be real and indicate that removal rate at 5 min exceeds production rate. /10/ Hyperventilation to alveolar pCO_2 of 11-15 mm Hg. /11/ Radial artery. /12/ Arm vein.

Contributor: Hegnauer, A. H.

References: [1] Cook, L. C., and Hurst, R. H., J. Biol. Chem. 79:443, 1933. [2] Bock, A. V., Dill, D. B., and Edwards, H. T., J. Clin. Invest. 11:775, 1932.

63. ARTERIO-VENOUS GLUCOSE DIFFERENCES AS INFLUENCED BY ALIMENTARY HYPERGLYCEMIA: MAN

Non-glucose reducing substances are reported as glucose with the exception of Lines 7-12 where the analytical method employed excludes non-glucose reducing substances. The values presented in Lines 7-12 are, therefore, accurate reflections of true blood glucose and A-V differences.

	Subjects	Observation[1] hr	Arterial Blood	Venous Blood	A-V Difference	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
	25 g Glucose					
1	6[2]	0	91.5(72-121)	89(67-121)	2.5(0-5)	1
2		0.5	218(188-258)	165(149-180)	53(32-80)	1
	50 g Glucose					
3	10[3]	0	85(68-108)	77(66-89)	9(-1 to +34)	2
4		0.5	126(98-158)	106(78-128)	21(8-50)	2
5		1	101(74-144)	88(63-128)	13(-1 to +30)	2
6		2	86(68-124)	79(62-125)	7(-7 to +17)	2
	100 g Glucose					
7	16[4]	0	91(83-102)[5]	86(75-98)	5(1-13)	3
8		0.5	160(133-189)[5]	126(96-150)	34(20-53)	3
9		1	142(95-190)[5]	108(71-140)	34(18-55)	3
10		2	122(100-165)[5]	96(70-142)	26(11-34)	3
11		3	102(64-144)[5]	85(50-131)	17(3-35)	3
12		4	82(57-119)[5]	73(53-94)	9(1-25)	3
13	7[6]	0	101(94-105)	101(93-105)	0(-1 to +4)	4
14		0.5	183(147-214)	140(110-163)	43(27-81)	4
15		1	158(118-190)	109(81-134)	49(28-81)	4
16		2	120(106-144)	86(61-107)	34(26-45)	4
17		3	103(94-108)	87(80-98)	16(10-28)	4
	100 g Galactose					
18	3[6]	0	96(95-96)	95(93-97)	1(-1 to +2)	4
19		0.5	148(126-174)	133(117-153)	15(9-21)	4
20		1	182(152-218)	162(142-182)	20(12-36)	4
21		2	238(212-278)	221(195-261)	17(16-17)	4
22		3	186(180-197)	187(173-215)	-2(-18 to +9)	4
23		4	110	109	1	4
	100 g Fructose					
24	4[6]	0	99(93-103)	98(87-105)	1.1(-2 to +6)	4
25		0.5	122(107-139)	101(76-130)	22(9-45)	4
26		1	118(112-125)	97(79-116)	21(9-33)	4
27		2	112(109-114)	103(96-109)	9(5-13)	4
28		2.5	105(98-109)	90(84-100)	15(8-25)	4
	70-100 g Starch					
29	2[6]	0	98(95-100)	95(93-96)	3(-1 to +7)	4
30		0.5	158(151-166)	119(118-120)	35(23-46)	4
31		1	146(140-152)	102(98-107)	44(42-45)	4
32		2	105(91-119)	81(76-86)	24(15-33)	4

/1/ After ingestion. /2/ Glycosuric subjects, but without clinical signs or symptoms of diabetes; method not stated. /3/ Modification of method of Benedict (1925). /4/ Copper iodometric analysis of zinc sulfate-barium hydroxide precipitates of whole blood; anticoagulant = potassium oxalate-sodium fluoride; accuracy = 1 mg/100 ml. Normal subjects. Rated abnormal and therefore excluded: subjects with arterial peaks exceeding 190 mg/100 ml, with venous peaks exceeding 150 mg/ml, and in whom use continued into second hr. /5/ Finger-tip blood, demonstrated to be arterial with respect to glucose content. /6/ Method of Folin and Wu (1920). Since "time" coordinates of original data did not correspond, in all cases, to those employed in this table, data of individual experiments were plotted and curves drawn. Values for desired times after sugar ingestion were taken from the plotted curves; tabulated data are means and ranges of these values.

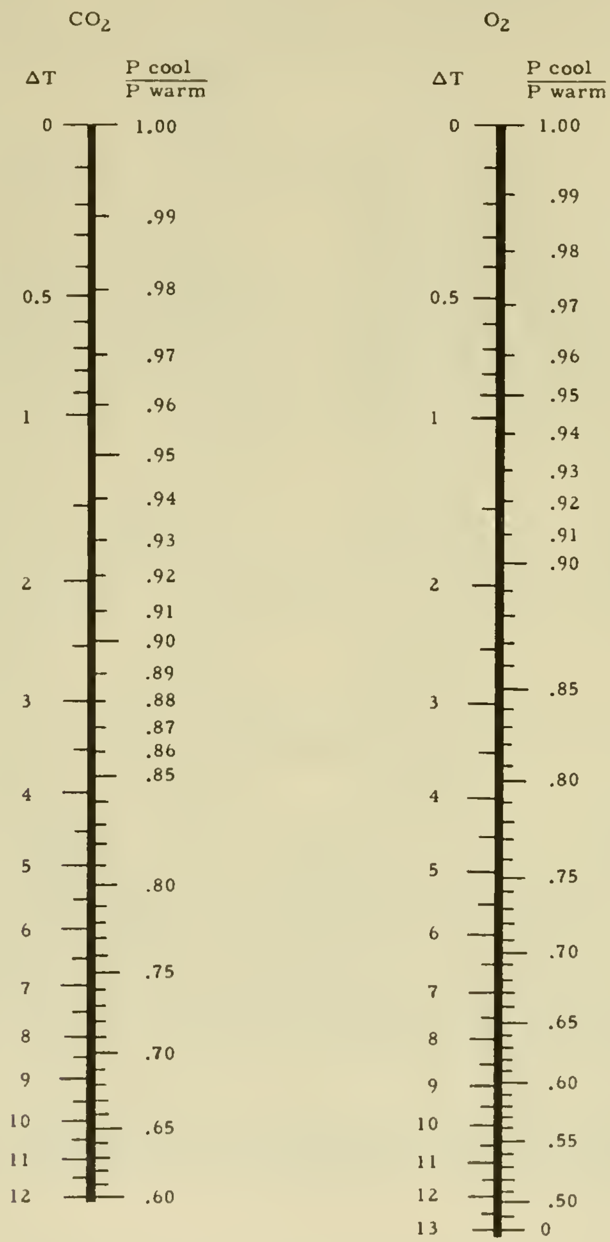
Contributor: Hegnauer, A. H.

References: [1] Rabinowitch, I. M., Brit. J. Exp. Path. 8:76, 1927. [2] Friedenson, M., Rosenbaum, M. K., Thalheimer, E. J., and Peters, J. P., J. Biol. Chem. 80:269, 1928. [3] Somogyi, M. J., ibid 174:189, 1948. [4] Foster, G. L., ibid 55:291, 1923.

64. EFFECT OF TEMPERATURE CHANGE ON BLOOD CO_2 AND O_2 PRESSURES: MAN, DOG

These line charts illustrate the effect of changes in temperature on CO_2 and O_2 tensions in human or dog blood sealed in an anaerobic environment. The values are applicable to either in vitro or in vivo conditions. Error increases progressively as pH and temperature deviate from standard values of 7.4 and 37°C respectively.

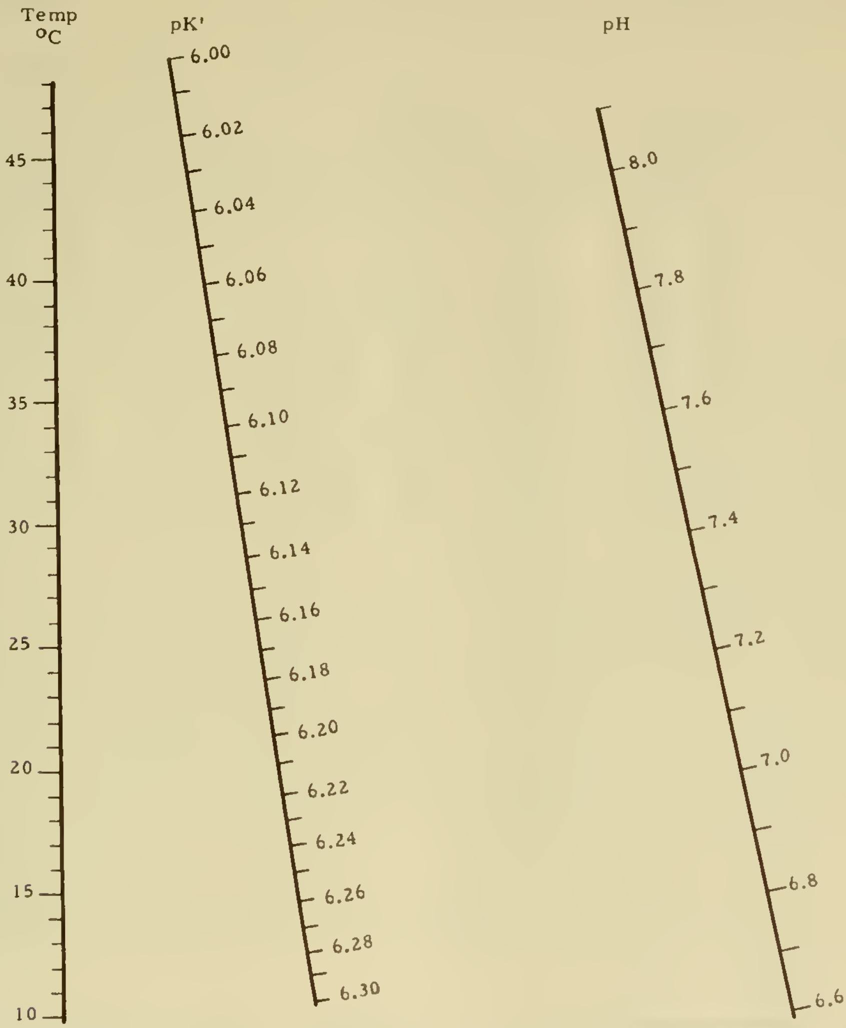
ΔT = temperature change in °C.



Contributor: Severinghaus, J. W.

65. TEMPERATURE AND pH VS SERUM pK': MAN, DOG

This nomogram allows for calculation of serum pK' for carbonic acid in man and dog when pH and temperature are known. Mean pK' at 37.5°C and pH 7.40 = 6.090.



Contributor: Severinghaus, J. W.

Reference: Severinghaus, J. W., Stupfel, M., and Bradley, A. F., J. Appl. Physiol. 9:197, 1956.

66. H_2CO_3 DISSOCIATION CONSTANTS: MAN, DOG, OX

The first apparent dissociation constants of H_2CO_3 are the same for man, dog, and ox. Methods used were gasometric or glass electrode. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Medium	Temp, °C	Dissociation Constant	Reference
	(A)	(B)	(C)	(D)
1	Plasma, pH 7.4	37	6.09(6.088-6.098)[1]	1
	Serum			
2	Normal	20	6.183(6.163-6.208)	2
3	Normal	38	6.11(6.097-6.122)	2-4
4	Nephritis	38	(6.108-6.134)	2-4
	RBC			
5	Reduced	37	5.98[2]	3
6	Oxidized	37	6.04[3]	3

/1/ Range varies with pH (7.6-7.1). /2/ Variation with pH; pK' = 7.275-0.18 pH. /3/ Variation with pH; pK' = 7.120-0.18 pH.

Contributors: Bartels, H., and Opitz, E.

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Data are for normal blood at temperatures corrected to 37°C. [1] Values for oxygenated blood are means of values in the literature, the 100% range being approximately ± 5 ml gas per 100 ml blood; other data are calculations based upon these means. [2-11] Major factors which influence CO_2 absorption include state of oxygenation, temperature, hemoglobin concentration, and alkali reserve. [1,6-9,11-13]

	pCO_2 mm Hg	Reduced (R) Oxygenated (O)	Total CO_2 vol %			Free CO_2[1] vol %			Total Combined CO_2[2] vol %			Plasma[6] pH
			Whole[3] Blood	RBC[4]	Plasma[5]	Whole Blood	RBC	Plasma	Whole Blood	RBC	Plasma	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
1	10	R	32.9	24.0	39.8	0.64	0.58	0.70	32.3	23.4	39.1	7.86
2		O	27.6	17.8	35.1	0.64	0.58	0.70	27.0	17.2	34.4	7.80
3	20	R	42.3	31.5	50.8	1.29	1.16	1.40	41.0	30.3	49.4	7.66
4		O	36.8	25.3	46.0	1.29	1.16	1.40	35.5	24.1	44.6	7.61
5	30	R	48.8	37.2	58.1	1.94	1.74	2.10	46.9	35.5	56.0	7.54
6		O	43.2	30.1	53.6	1.94	1.74	2.10	41.3	28.4	51.5	7.50
7	40	R	54.1	42.4	63.8	2.58	2.32	2.80	51.5	40.1	61.0	7.45
8		O	48.5	35.5	59.1	2.58	2.32	2.80	45.9	33.2	56.3	7.41
9	50	R	58.6	46.7	68.6	3.22	2.90	3.50	55.4	43.8	65.1	7.38
10		O	52.8	39.3	63.9	3.22	2.90	3.50	49.6	36.4	60.4	7.35
11	60	R	62.6	50.7	72.6	3.87	3.47	4.20	58.7	47.2	68.4	7.32
12		O	56.7	42.8	68.1	3.87	3.47	4.20	52.8	39.3	63.9	7.29
13	70	R	66.6	54.7	76.6	4.52	4.05	4.90	62.1	50.7	71.7	7.27
14		O	60.5	46.8	72.0	4.52	4.05	4.90	56.0	42.7	67.1	7.25
15	80	R	70.2	58.6	80.1	5.16	4.63	5.60	65.0	54.0	74.5	7.23
16		O	63.9	50.1	75.5	5.16	4.63	5.60	58.7	45.5	69.9	7.21

/1/ Calculated by equation: $[H_2CO_3] = 100\alpha pCO_2/760$, where $[H_2CO_3]$ = vol % of free CO_2, and alpha is the solubility coefficient for CO_2 with the values at 37°C of 0.490 for whole blood, 0.440 for cells, and 0.531 for plasma. [13-15] /2/ Includes both HCO_3^- and $NHCOO^-$ as the rounded difference between total and free CO_2. /3/ Reduced blood values calculated from: $[CO_2]O + [CO_2]b = [CO_2]R$, where $[CO_2]O$ = total CO_2 of oxygenated blood at a given CO_2 pressure, $[CO_2]b$ = average increase in bound CO_2 with complete reduction, and $[CO_2]R$ = total CO_2 of reduced blood. [2-12] /4/ For cells in contact with plasma at equilibration. Calculations based upon assumed mean cell volume of 45 ml/100 ml arterial blood (corrected for pH and oxygenation), and derived by equation: $[CO_2]c = ([CO_2]b - [CO_2]p \times [1-h])\, 1/h$, where CO_2 is in ml/100 ml of cells (c), blood (b), or plasma (p), and h is the cell volume as a decimal fraction of blood volume for any given pH and oxygenation. [13,16-18] /5/ For plasma in contact with cells at equilibration. Calculations are based upon CO_2 of whole blood using "f" values of Van Slyke, Sendroy, and Liu, and an estimated O_2 capacity, pH, and state of oxygenation. O_2 capacity estimated from CO_2 absorption curve of oxygenated whole blood using Cartesian nomogram of Henderson, Bock, Dill and Edwards. Plasma $CO_2 = [CO_2]b \times$ "f". [18,19] /6/ Calculated from equation: $pH = pK_1 + \log\frac{[CO_2]p - 0.0699\, pCO_2}{0.0699\, pCO_2}$, where $[CO_2]p$ is total vol % of plasma CO_2, and 0.0699 (the factor, $\alpha p/7.6$) expresses dissolved CO_2 in vol % of plasma. pK_1, taken as equal to 6.11 at 37°C, is the Hastings, Sendroy, and Van Slyke average for human serum at 38°C plus a temperature correction of 0.005 at 37°C. [13,15,20]

Contributor: Root, R. W.

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68. BLOOD CO_2 ABSORPTION AS FUNCTION OF CO_2 PRESSURE: ANIMALS

Values for CO_2 are volumes absorbed gas per 100 ml whole blood or serum, obtained by interpolation from smoothed CO_2 absorption curves. In all cases, except the squid, CO_2 values are for oxygenated blood or serum.

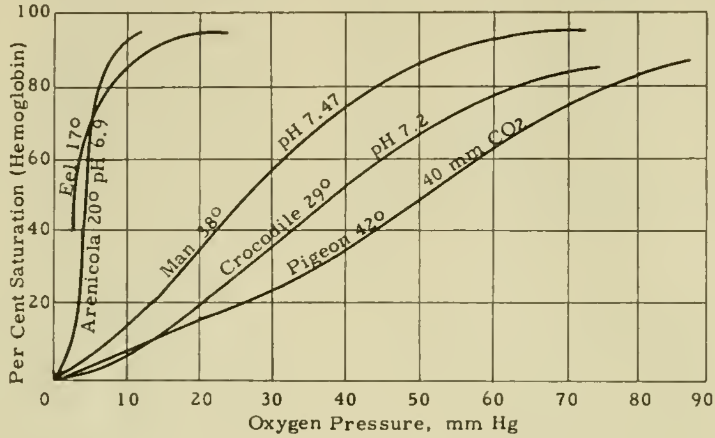
	Animal	Total CO_2 at pCO_2 of: 10 mm	20 mm	30 mm	40 mm	50 mm	60 mm	70 mm	80 mm	Temp °C	$\left[\frac{-\Delta BHCO_3}{\Delta O_2}\right]^1$	at pCO_2	Physiological pCO_2 Arterial	Venous	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)
1	Man	27.6	36.8	43.2	48.5	52.8	56.7	60.5	63.9	37	0.27	40	41	46.5	B-L, a; M, N, 1
2	Horse (Equus caballus)	19.3	27.3	33.2	37.9	42.2	46.2	50.2		38	0.35	40	41.6	49.2	B-L, 2; M, N, 3
3	Goose (Anser a. domesticus)	28.8	38.5	45.8	51.5	55.5	58.2	60.2	61.6	40	0.32	40	42-44	53-55	B-N, 4
4	Crocodile (Crocodilus acutus)	11.2	17.5	22.2	26.0	28.8	31.5	34.0	36.2	29	0.52	30			B-L, 5
5	Turtle[2] (Pseudemys troosti)	64.0	70.9	76.0	80.3	83.9	87.1	89.8	92.3	25	0.44	30	~28		B-N, 6, 7
6	Frog (Rana catesbeiana)	42.5	51.7	58.4	63.0	65.8	68.5	70.0		15	0.46	25	aortic blood ~25		B-N, 8
7	Congo snake[3] (Amphiuma tridactyla)	41.7	47.1	50.9	53.9	56.4	58.7	60.8	63.2	24	0.45[4]	25			B-L, 9
8	Blackfish (Tautoga onitis)	14.2	19.5	23.5	27.3	30.5	32.8	35.0	37.0	15	0.43-0.95[5]	10	~2[6]	~10[6]	B-L, 10, 11; M, N, 12
9	Carp (Cyprinus carpio)	22.3	29.6	33.7	36.7	39.3	41.4	43.6		15-16	0.54[7]	10	3-5	5-10	B-L, 13-15, M, N, 14, 16
10	Mackerel (Scomber scombrus)	21.0	28.5	33.9	37.8	41.0	43.8	46.2	48.9	20	0.40	10	~2[6]	~10[6]	B-N, 12
11	Skate (Raia oscillata)	14.2	20.5							25	0.0[8]		1.4		B-C, J-M, 17
12	Echiuroid worm[9] (Urechis caupo)	10.5	14.0	16.0	18.0	20.0				18.5	0.0[10]		celomic fluid ~7		B-F, J-N, 18
13	Horsehoe crab[12] (Limulus polyphemus)	6.7	8.9	10.2	11.4	12.6				22	0.0[11]				B-F, J-L, 19
14	Squid[12] (Loligo pealei)	11.7	17.0	19.3	21.2	22.2	23.0	23.9	24.8	23	0.69	10	2.2	6.0	B-L, 19; M, N, 20
15	Whelk[12] (Busycon canaliculatum)	24.6	32.2	36.5	39.6	42.2	44.2	46.5	48.7	24	-0.64[13]	10			B-L, 19

/1/ $-\Delta BHCO_3/\Delta O_2$ indicates approximate magnitude of Haldane effect; negative sign implies that oxygenation reduces amount of bound CO_2. ΔO_2 was taken as equal to O_2 capacity or as difference between bound O_2 values in oxygenated and in reduced blood. /2/ Data compare favorably with Pseudemys concinna as to height of CO_2 absorption curve, but slope is different. /3/ Average of two blood samples with cell volume of 18.5%. /4/ Value obtained from oxygenated and reduced CO_2 curves of one blood sample with O_2 capacity of 4.4 ml/100 ml blood [9]. /5/ Ratio is not constant for a given CO_2 tension but increases in magnitude with oxygenation of blood (atypical Haldane effect) [10, 11]. /6/ Estimated from arterial and venous blood of sea-robin, Prionotus carolinus [12]. /7/ Average from two sources (0.45 and 0.64). /8/ An unusually low hemoglobin concentration (about 1/4 that for man) may be responsible for obscuring Haldane effect [17]. /9/ Blood, containing hemoglobin in red blood corpuscles, from celomic cavity [18]. /10/ Bohr effect is absent [18]. /11/ Reversed Bohr effect in this species; on a theoretical basis a reversed Haldane effect might be expected. [19] /12/ Hemocyanin instead of hemoglobin. /13/ Negative sign before number indicates reversed Haldane effect, i.e., oxygenation increases bound CO_2 [19].

Contributor: Root, R. W.

References: [1] Albritton, E. C., "Standard Values in Blood," Philadelphia: W. B. Saunders Co., 1952 (values from Table 94). [2] Van Slyke, D. D., Hastings, A. B., and Neill, J. M., J. Biol. Chem. 54:507, 1922. [3] Henderson, L. J., "Blood: A Study in General Physiology," New Haven: Yale Univ. Press, 1928. [4] Wastl, H., and Leiner, G., Arch. ges. Physiol. 227:460, 1931. [5] Dill, D. B., and Edwards, H. T., J. Biol. Chem. 90:515, 1931. [6] Wilson, J. W., J. Cellul. Physiol. 13:315, 1939. [7] Southworth, F. C., and Redfield, A. C., J. Gen. Physiol. 9:387, 1926. [8] Wastl, H., and Seliškar, A., J. Physiol., Lond. 60:264, 1925. [9] Scott, W. J., Biol. Bull. 61:211, 1931. [10] Root, R. W., and Irving, L., J. Cellul. Physiol. 16:85, 1940. [11] Root, R. W., and Irving, L., Biol. Bull. 81:307, 1941. [12] Root, R. W., ibid 61:427, 1931. [13] Wastl, H., Biochem. Zschr. 197:363, 1928. [14] Ferguson, J. K., and Black, E. C., Biol. Bull. 80:139, 1941. [15] Black, E. C., ibid 79:215, 1940. [16] Hoar, W. S., Black, V. S., and Black, E. C., "Some Aspects of the Physiology of Fish," Toronto: Univ. of Toronto Press, 1951. [17] Dill, D. B., Edwards, H. T., and Florkin, M., Biol. Bull. 52:23, 1932. [18] Redfield, A. C., and Florkin, M., ibid 61:185, 1931. [19] Redfield, A. C., Coolidge, T., and Hurd, A. L., J. Biol. Chem. 69:475, 1926. [20] Redfield, A. C., and Goodkind, R., J. Exp. Biol., Lond. 6:340, 1929.

Lowest oxygen tension, in mm Hg, at which respiratory blood pigment (hemoglobin, unless otherwise indicated) is 95% or more saturated, is referred to as tension of saturation; that at which the pigment is 50% saturated (i.e., when unoxygenated pigment equals oxygenated pigment) is called the tension of half-saturation and indicated as "t. ½ sat." The tension of half-saturation for a specific pigment establishes the upper limit of tissue oxygen tension and the lower limit of environmental oxygen for the function of that pigment. When per cent saturation is plotted as ordinate against oxygen pressure as abscissa, the "position" (O_2 pressure required to produce 50% saturation) of the resultant dissociation curves differs from species to species, and varies greatly within the same species with changes in pH, temperature, and dilution. The "shape" is not affected by these factors, in that the curves may be superimposed upon each other by multiplying pO_2 (t. ½ sat.) of standard curve for man by a suitable factor "f" [1]. This is true only as a first approximation, for certain fish show some change in shape with changes in pCO_2, and sheep hemoglobin at low O_2 pressures has definite changes in shape as pH is varied [2]. The figure below illustrates dissociation curves for two animals whose blood has a low affinity for oxygen, i.e., a high t. ½ sat. (pigeon, crocodile), and for two others (arenicola, eel) showing a high affinity and low t. ½ sat. In the tables below, values in brackets are calculated "f" factors.



Part I: MAN

	pO_2 mm Hg (A)	% Saturation (B)	pH (C)	Temperature °C (D)	pCO_2 mm Hg (E)	Reference (F)
1	3.7	5.0	7.40	37.0	47.4	A-E 3; F 4, 5
2	8.2	10.0	7.40	37.0	47.0	A-E 3; F 4, 5
3	10.9	15.0	7.40	37.0	46.6	A-E 3; F 4, 5
4	13.4	20.0	7.40	37.0	46.2	A-E 3; F 4, 5
5	17.9	30.0	7.40	37.0	45.3	A-E 3; F 4, 5
6	22.0	40.0	7.40	37.0	44.6	A-E 3; F 4, 5
7	26.3[1]	50.0[1]	7.40[1]	37.0[1]	43.8[1]	A-E 3; F 4, 5
8	31.1	60.0	7.40	37.0	43.0	A-E 3; F 4, 5
9	36.1	70.0	7.40	37.0	42.2	A-E 3; F 4, 5
10	45.7	80.0	7.40	37.0	41.5	A-E 3; F 4, 5
11	51.7	85.0	7.40	37.0	41.1	A-E 3; F 4, 5
12	61.4	90.0	7.40	37.0	40.7	A-E 3; F 4, 5
13	80.0	95.0	7.40	37.0	40.3	A-E 3; F 4, 5
14	113.0	98.0	7.40	37.0	40.0	A-E 3; F 4, 5

/1/ Standard reference condition with an "f" factor taken as [1.00].

Part II: MAMMALS

	Animal (A)	t. ½ sat. mm Hg (B)	pH (C)	Temperature °C (D)	pCO_2 mm Hg (E)	Reference (F)
1	Man [1.48]	(39.0)[1]	7.00	37.0	142	A-D 3; E 4, 5
2	Man [1.35]	(35.5)[1]	7.10	37.0	110	A-D 3; E 4, 5
3	Man [1.22]	32.2	7.20	37.0	84	A-D 3; E 4, 5
4	Man [1.11]	29.2	7.30	37.0	60	A-D 3; E 4, 5

/1/ Values in parentheses are calculated. In calculations at 37°C, $\mathrm{pH} = 6.15 + \log\frac{(\text{total } CO_2) - 0.0290\ pCO_2}{0.0290\ pCO_2}$, where 6.15 and 0.0290 are the pK' and CO_2 factors, respectively, for whole blood.

Values in brackets are calculated "f" factors.

Part II: MAMMALS (Continued)

	Animal	t. ½ sat. mm Hg	pH	Temperature °C	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
5	Man [1.00]	26.3	7.40	37.0	44	A-D 3; E 4, 5
6	Man [0.90]	23.5	7.50	37.0	31	A-D 3; E 4, 5
7	Man [0.80]	21.0	7.60	37.0	22	A-D 3; E 4, 5
8	Man [0.71]	(18.5)[1]	7.70	37.0	15	A-D 3; E 4, 5
9	Man [0.29]	7.4	7.40	10.0		6
10	Man [0.47]	12.4	7.40	20.0		6
11	Man [0.74]	19.6	7.40	30.0	(48)[1]	A-D 6; E 6, 7, 8
12	Man [1.00]	26.3	7.40	37.0	(44)[1]	A-D 6; E 6, 7, 8
13	Man [1.14]	30.0	7.40	40.0	(42)[1]	A-D 6; E 6, 7, 8
14	Man, at work [1.00]	26.5	7.40	37.5	34	9
15	Man, at altitude, 5400 m [0.97]	29.0	7.40	37.5	29	10, 11, 12
16	Man, terminal nephritis [1.14]	30.0	7.11	37.5	7	13
17	Man, terminal nephritis [1.79]	47.0	6.83	37.5	40	13
18	Man, pernicious anemia [1.18]	31.0	7.40	37.5	48	14
19	Man, diabetic coma [1.03]	27.0	7.40	37.5	2	15
20	Man, diabetic coma [1.25]	33.0	6.86	37.5	40	15
21	Man, diabetic coma [1.33]	35.0	7.40	37.5	3	15
22	Man, diabetic coma [1.52]	40.0	6.92	37.5	40	15
23	Cat [1.44]	38.0	7.40	37.0		16
24	Cat [1.33]	35.0	7.40	37.0	44	17
25	Cat	50.0	6.80			18
26	Dog [1.06]	28.0	7.40	37.5	38	19
27	Dog (Canis familiaris)	29.4	7.10	37.0		18
28	Dog[2]	0.6	7.00	20.0		20
29	Dog[2]	0.5	9.20	20.0		20
30	Fox	(21)[1]			10	18
31	Fox (Vulpes fulva)	37.0		37.5	40	18
32	Goat (Capra hircus), adult	28-33		38.0	50	21
33	Goat, fetal	25.0		38.0	50	21
34	Goat, maternal	40		38.0	50	21
35	Horse [1.03]	27.0	7.40	37.5	50	22
36	Horse[2]	3.7	7.00	37.0		23
37	Horse[2]	3.4	7.200	37.0		23
38	Horse[2]	3.2	7.40	37.0		23
39	Horse[2]	1.5	7.40	30.0		23
40	Horse[2]	1.1	7.40	27.0		23
41	Horse[2]	0.5	7.40	20.0		23
42	Horse[2]	0.3	7.40	17.0		23
43	Llama (Lama huanachus glama) [0.76]	20.0	7.40	39.0		24
44	Llama (L. peruana)	22.0		38.0	43	18
45	Marmot	23.8		38.0	40	18
46	Mouse (Mus musculus)	72.0		38.0	40	18
47	Ox [1.13]	29.8	(7.40)[1]	37.0	29.8	25
48	Ox[2]	0.6	7.00	19.0		20
49	Ox[2]	0.5	9.20	19.0		20
50	Peccary [1.10]	29.0	7.40	37.0		25
51	Porpoise (Phocaena phocaena) [1.14]	30.0		38.0	46	26
52	Rabbit [1.20]	31.6	7.40	38.6	32	24
53	Rat [1.52]	40.0	7.40	37.0		16
54	Rat, kangaroo (Dipodomys spectabilis) [1.93]	51.0		37.0	40	27
55	Rat, white (Rattus norvegicus) [2.13]	56.0		37.0	40	27
56	Sea lion (Eumetopiaes stelleri) [1.52]	40.0		38.0	44	28
57	Seal	25			10	18
58	Seal (Phoca vitulina)	31		38.0	40	18
59	Seal, harbor (P. vitulina) [1.06]	28.0		37.0	40	29

/1/ Values in parentheses are calculated. In calculations at 37°C, $pH = 6.15 + \log\frac{(\text{total } CO_2) - 0.0290\ pCO_2}{0.0290\ pCO_2}$, where 6.15 and 0.0290 are the pK' and CO_2 factors, respectively, for whole blood. /2/ Myoglobin (myohemoglobin, muscle hemoglobin). Oxygen dissociation curves of myoglobin are rectangular hyperbolas and are defined by giving pO_2 for 50% saturation.

Values in brackets are calculated "f" factors.

Part II: MAMMALS (Concluded)

	Animal	t. ½ sat. mm Hg	pH	Temperature °C	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
60	Sheep [1.48]	39.0	(7.40)[1]	37.0		25
61	Sheep (Ovis aries)	37.0		39.0	40	18
62	Sheep, diluted blood and Hb	3.0	9.30	19.0	0.015	17
63	Sheep[2]	0.5	9.20	20.0		20
64	Swine [1.28]	33.7	(7.40)[1]	37.0		25
65	Vicuna (Lama vicugna) [0.69]	18.0	7.40	39.0		24
66	Viscacha (Lagostomus sp) [0.99]	26.0	7.40	38.6	28	24

/1/ Values in parentheses are calculated. In calculations at 37°C, $pH = 6.15 + \log\frac{(\text{total } CO_2) - 0.0290\ pCO_2}{0.0290\ pCO_2}$, where 6.15 and 0.0290 are the pK' and CO_2 factors, respectively, for whole blood. /2/ Myoglobin (myohemoglobin, muscle hemoglobin). Oxygen dissociation curves of myoglobin are rectangular hyperbolas and are defined by giving pO_2 for 50% saturation.

Part III: BIRDS

	Animal	t. ½ sat. mm Hg	pH	Temperature °C	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Chicken [1.98]	51	7.14	40.0	37	30
2	Chicken	58		38.0	31	31
3	Chicken (Gallus domesticus)	52	7.10	37.5		32
4	Chicken, Hb solution [2.35]	62.0	7.10	37.0		32
5	Chicken, Hb solution [1.58]	41.7	7.40	37.0		32
6	Chicken, Hb solution [1.12]	29.5	7.70	37.0		32
7	Crow	53.0		42.0	40	33
8	Duck	45	7.10	37.5		31, 32
9	Duck (Anas sp)	42.0		37.5	40	18, 33
10	Duck, domestic [1.71]	45		37.0		32
11	Duck, muscovy [1.48]	39.0		37.0		32
12	Duck, muscovy, Hb solution [2.20]	58.0	7.10	37.0		32
13	Goose	37.5		42.0	50	33
14	Goose	45.0	7.10	37.5		18
15	Goose	(24)[1]			10	18
16	Goose	35.7			40	18
17	Goose, domestic [1.64]	43.0		37.0		32
18	Goose[2]	0.7	9.20	20.0		20
19	Huallata (Chloephaga melanoptera)	33.0	7.35	40.0		24
20	Ostrich (Rhea americana)	26.0	7.35	40.0		24
21	Pheasant	50.0	7.10	37.5		18
22	Pheasant, ringnecked [1.82]	48.0		37.0		32
23	Pigeon	35.0		37.5	40	17, 34
24	Pigeon	40.0	7.10	37.5		18
25	Pigeon, domestic [1.48]	39.0		37.0		32
26	Pigeon, domestic	44.0		40.0		32

/1/ Values in parentheses are calculated. In calculations at 37°C, $pH = 6.15 + \log\frac{(\text{total } CO_2) - 0.0290\ pCO_2}{0.0290\ pCO_2}$, where 6.15 and 0.0290 are the pK' and CO_2 factors, respectively, for whole blood. /2/ Myoglobin (myohemoglobin, muscle hemoglobin). Oxygen dissociation curves of myoglobin are rectangular hyperbolas and are defined by giving pO_2 for 50% saturation.

Part IV: REPTILES

	Animal	t. ½ sat. mm Hg	pH	Temperature °C	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Alligator	11			10	18
2	Alligator	28			40	18
3	Alligator (Alligator mississippiensis) [1.06]	28.0	7.60	29.0	42.0	35
4	Chuckwalla (Sauromalus obesus) [0.91]	24.0	7.60	20.0	37.0	36

Values in brackets are calculated "f" factors.

Part IV: REPTILES (Concluded)

	Animal	t. ½ sat. mm Hg	pH	Temperature °C	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
5	Chuckwalla (S. obesus) [2.36]	62.0		37.0	(55)[1]	36
6	Crocodile (Crocodilus acutus) [1.0]	26.0	(7.40)[1]	29.0	(50)[1]	37
7	Crocodile (C. acutus) [2.0]	53.0	(7.40)[1]	37.0	(45)[1]	37
8	Crocodile (C. acutus)	38.0	7.20	29.0		37
9	Gila monster (Heloderma suspectum) [1.22]	32.0	7.40	20.0	36.0	38
10	Gila monster (H. suspectum) [2.24]	59.0	7.40	37.0	(32)[1]	38
11	Gila monster (H. suspectum)	31.0	7.32	20.0	37.0	b
12	Tortoise (Terrapene carolina)[2]	12.0	7.40	25.5		18
13	Turtle (Caretta caretta)[2]	28.5	7.40	25.5		18
14	Turtle (Chelonis mydras)[2]	19.0	7.40	25.5		18
15	Turtle (Chelydra serpentina)[2]	14.0	7.40	25.5		39, 40
16	Turtle (Pseudemya concinna) [0.77]	20.0		25.0	40.0	41
17	Turtle (P. elegans)	28.0		25.0	27.0	18
18	Turtle (P. scripta)[2]	15.8	7.40	25.5		18
19	Turtle (P. troostii)	26.0		25.0	34.0	18, 42
20	Turtle, painted (Chrysemis picta)[2]	15.0	7.40	25.5		18

/1/ Values in parentheses are calculated. In calculations at 37°C, $pH = 6.15 + \log\frac{(\text{total } CO_2) - 0.0290\ pCO_2}{0.0290\ pCO_2}$, where 6.15 and 0.0290 are the pK' and CO_2 factors, respectively, for whole blood. /2/ Hemoglobin solutions.

Part V: AMPHIBIANS

	Animal	t. ½ sat. mm Hg	pH	Temperature °C	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Congo eel (Amphiuma tridactyla) [1.14]	30.0		26.0	43.0	43
2	Frog (Rana esculenta)	11.0			1-2	18
3	Frog (R. esculenta)	17.0			10.0	18
4	Frog (R. esculenta)	49.0			10.0	18
5	Frog (R. catesbiana), adult[1]	26.0	7.38	25.4		44
6	Frog (R. catesbiana), adult[1]	13.5	7.40	20.0		45
7	Frog (R. catesbiana), larva[1]	6.0	7.38	25.4		44
8	Frog (R. catesbiana), larva[1]	4.6	7.32	20.0		45
9	Frog (R. catesbiana), tadpole[1]	5.0	6.80			44
10	Toad (Bufo sp)[1]	30.0	7.38	25.4		18, 46
11	(Amphiuma sp)[1]	15.0	7.38	25.4		43, 46
12	(Cryptobranchus sp)[1]	18.0	7.38	25.4		18, 46
13	(Desmognathus sp)[1]	5.0	7.38	25.4		18, 46
14	(Triturus sp)[1]	7.5	7.38	25.4		18, 46

/1/ Hemoglobin solutions.

Part VI: FISH

	Animal	t. ½ sat. mm Hg	pH	Temperature °C	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Baiara	8.0		28.0	0	18
2	Baiara	22.0			25.0	18
3	Bom-bom	11.0		28.0	0	18
4	Bom-bom	13.0			25.0	18
5	Bowfin	4.0		15.0	1-2	18
6	Bowfin	9.0			10.0	18
7	Carp	8.0			10.0	18
8	Carp	13.0		18.0	30.0	47
9	Carp (Cyprinus carpio)	5.0		15.0	1-2	18
10	Catfish	1.4			1-2	18
11	Catfish	5.0			10.0	18
12	Catfish	1.4		15.0	0-1	18
13	Cod	15.0		14.0	<0.3	18
14	Eel, electric	12.0		28.0	0	18

69. DATA FOR CONSTRUCTING BLOOD O_2 DISSOCIATION CURVES (Continued)

Part VI: FISH (Concluded)

	Animal	t. ½ sat. mm Hg	pH	Temperature °C	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
15	Eel, electric	18.0			25.0	18
16	Eel, salt water (Anguilla bostoniensis)	4.0		17.0	0.3	18
17	Haimara	8.0		28.0	0	18
18	Hassa	11.0		28.0	0	18
19	Hassa	20.0			25.0	18
20	Mackerel (Scomber scombrus)	52.0			10.0	18, 48
21	Mackerel (S. scombrus)	17.0	8.0	20.0	1.0	48
22	Mackerel (S. scombrus), dilute Hb solution	18.0	7.38	25.0		18
23	Paku	12.0		28.0	0	18
24	Paku	55.0			25.0	18
25	Plaice	12.0		16.5	0.3	18
26	Ray (Raja sp)[1]	26.0	7.38	25.0		49
27	Ray (Raja sp)	45.0		25.0	1.0	49
28	Remora (Echeneis naucrates)[1]	11.0	7.38	25.0		49
29	Remora (E. naucrates)[1]	53.0	6.80	25.0		49
30	Salmon, Atlantic, brackish water	23.0		15.0	1-2	18
31	Salmon, Atlantic, fresh-water	21.0		15.0	1-2	50
32	Salmon, Atlantic, fresh-water	35.0		15.0	10.0	18, 50
33	Scup (Stenotomus chrysops)[1]	6.4	7.38	25.0		49
34	Sea robin (Prionatus carolinas)[1]	21.0	7.38	25.0		49
35	Sea robin (P. carolinas)	17.0	7.70	20.0	1.0	48
36	Shark (Mustelus canis)[1]	7.0	7.40	25.0		49
37	Shark (M. canis)[1]	12.0	6.80	25.0		49
38	Shark (Hypoprion brevirostris)[1]	7.6	7.40	25.0		51
39	Skate (Raja oscillata)	20.0	7.80	10.4	1.0	52
40	Skate (R. oscillata)	45.0		25.0	1.0	52
41	Skate (R. oscillata)	98.0		37.0	1.0	52
42	Skate (R. oscillata)	11.0		0.2	1.0	52
43	Stingray (Dasyatus sp)[1]	13-15	7.40	25.0		51
44	Sucker	12.0		15.0	1-2	18
45	Sucker	43.0			10.0	18
46	Tautog (Tautoga onitus)[1]	6.0	7.38	25.0		49
47	Toadfish	14.0		20.0	1-2	18
48	Toadfish	33.0			10.0	18
49	Toadfish (Opsanus tau)[1]	3-4.4	7.38	25.0		49
50	Toadfish (O. tau)	13.0	7.70	20.0	1.0	48
51	Trout, brook	17.0		15.0	1-2	18
52	Trout, brook	42.0		15.0	10.0	18
53	Trout, brown	17.0		15.0	1-2	18
54	Trout, brown	39.0		15.0	10.0	18
55	Trout, rainbow	18.0		15.0	1-2	18
56	Trout, rainbow	35.0		15.0	10.0	18

/1/ Hemoglobin solutions.

Part VII: INVERTEBRATES

	Animal	t. ½ sat. mm Hg	pH	Temperature °C	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Anadara	10.0				18
2	Arenicola	1.8	7.3			18
3	Arenicola	1.8		17.0	0	18
4	Busycon[1]	6.0		23.0	13.5	53
5	Cancer[1]	12.0		23.0	0	18
6	Ceriodaphnia	0.8		17.0	0	18
7	Chironomus	0.2		17.0	0	18
8	Chironomus	0.6		17.0	0	18
9	Daphnia	3.1		17.0	0	18
10	Gastrophilus, concentrated	4.9		39.0		18

/1/ Hemocyanin.

Part VII: INVERTEBRATES (Concluded)

	Animal	t. ½ sat. mm Hg	pH	Temperature °C	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
11	Gastrophilus, dilute	0.02		39.0		18
12	Helix, summer[1]	12.0		20.0	0	18, 53
13	Helix, winter[1]	11.0	8.20	20.0		18
14	Homarus[1]	90.0	7.20			18
15	Limulus[1]	11.0			0	18
16	Limulus[1]	13.0	7.70			18
17	Loligo[1]	36.0		23.0	0	18, 54, 55
18	Nippostrongylus	<0.1		19.0		18
19	Octopus[1]	3.0		25.0	0.6	18, 56-58
20	Phascolosoma[2]	8.0		19.0		18
21	Planorbis	1.9		17.0	0	18
22	Planorbis	7.0		20.0	0	18
23	Sipunculus[2]	8.0		19.0	0.07-80	18
24	Spirographis[3]	27.0	7.70	20.0		18
25	Tubifex	0.6		17.0	0	18
26	Urechis[2]	12.3		19.0	8.6	18

/1/ Hemocyanin. /2/ Hemerythrin. /3/ Chlorocruorin.

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USE OF CHARTS:

Changes in temperature and pHs (serum) alter the position but not the shape of the oxygen dissociation curve. Dissociation curves for various values of pHs and temperature for man may be computed from the one standard curve for normal human blood at 37°, pHs 7.4, by multiplying all the pO_2 values by factors for temperature and pHs. The left-hand line gives factors for temperature, the next line factors for pHs. The two right-hand line graphs give the standard oxygen dissociation curve in a form more easily read than the usual graph. The computation is given by

$$P_{t,\,pH} = P \times f_t \times f_{pH}$$

where $P_{t,\,pH}$ is the pO_2 at temperature t and pH, P is the pO_2 at 37°, pHs 7.4 for the same % saturation, given on the standard curve, and f_t and f_{pH} are the multipliers obtained from the line charts.

Examples of the use of these charts follow:

1) Problem: Prepare a complete oxygen dissociation curve for 30°, pH 7.6.

Method: The factor for 30° is 0.74, and for pH 7.6 is 0.80. Their product is 0.59. Multiply all pO_2 values in the standard curve by 0.59; i.e., for 50% saturation, pO_2 in the new curve is 26.4 x 0.59 = 15.6 mm Hg.

2) Problem: Arterial blood taken during surgery had 88% saturation by Van Slyke manometric methods. pH was 7.56 at body temperature of 33.8°C. What is the pO_2?

Method: From the standard dissociation curve, right-hand line, at 88% saturation, pO_2 = 57 mm Hg. The factors are, for pH, 0.84 and for temperature, 0.87. pO_2 = 57 x 0.84 x 0.87 = 41.6 mm Hg in the patient.

To convert tension to saturation, factors are used as dividers:

3) Problem: Arterial blood from a febrile subject had a pO_2 of 73 mm Hg, determined at body temperature, 40°C, using a Roughton Scholander syringe. pHs, corrected to 40°, was 6.98. What is the % saturation?

Method: Factors are 1.14 for temperature, and 1.52 for pHs. $\frac{73}{1.14 \times 1.52}$ = 42.1 mm Hg. From the dissociation curve, this equals 77% saturation.

4) Problem: Blood taken from a heart-lung by-pass machine was found to have a pO_2 by polarograph of 65 mm Hg and pHs of 7.72, both having been measured at 37°. The blood in the machine was at 30°. What is the % saturation, and the pO_2, in the machine?

Method: Since the blood was warmed anaerobically to 37° for pHs and pO_2 measurement, its saturation was unchanged, and the only correction needed to calculate saturation is that for pHs. This, for 7.72 is 0.70. $\frac{65}{0.70}$ = 93 mm Hg, which from the dissociation curve reads 96.4% saturation.

To find pO_2 at 30°, first the pHs at 30° must be computed from the whole blood pHs factor, -0.0147 units per degree [1]. -7° x -0.0147 = +0.103. Inasmuch as pHs rises as temperature falls, 0.103 is added to 7.72 (= 7.82). The factor for pH 7.82 is 0.63 and for 30° is 0.74. 93 x 0.63 x 0.74 = 43.3 mm Hg pO_2 in the machine. A simpler method of correcting the pO_2 from 37° to 30° is given in the line chart on page 62 (correction of pO_2 and pCO_2 of blood *in vitro* for temperature changes).

The standard dissociation curve, and the pHs and temperature factors are taken from curves published by Dill and Forbes [2, 3]. Tensions at the high end of the curves were taken from Nahas, et al [4]. These are assumed to be average curves, subject to some variation in normals and perhaps great variation in disease, particularly diabetes and anemia. The chief reason for variation is failure of intracellular pHc, which actually determines the affinity of hemoglobin for oxygen, to be constantly related to serum pHs.

Contributor: Severinghaus, J. W.

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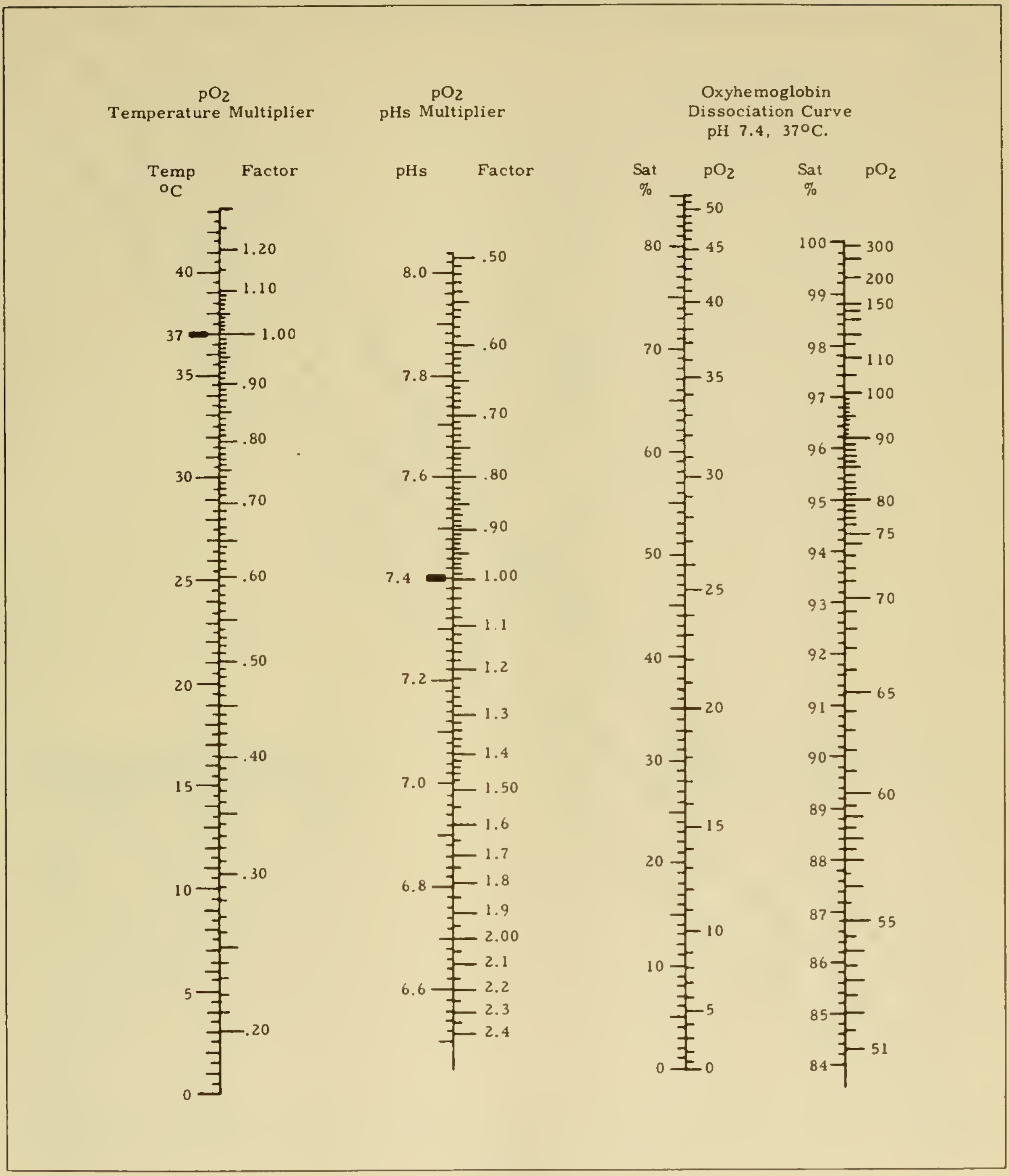
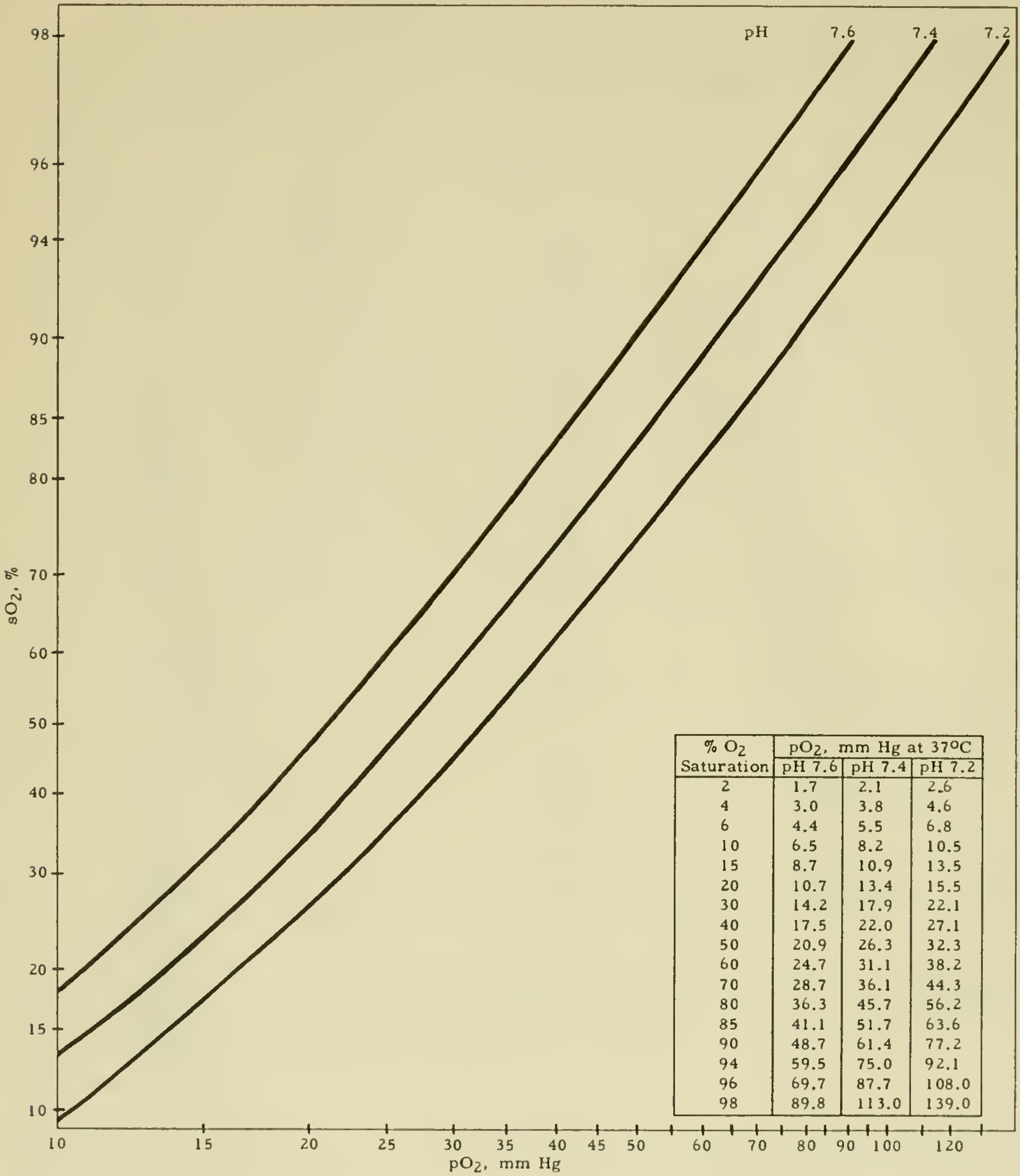


Contributor: Severinghaus, J. W.

71. BLOOD O_2 DISSOCIATION CURVES: MAN

Part I: AT VARIOUS pH VALUES

Theory and method of development of straight line curves given in headnote and in Parts I and II of Table 72.



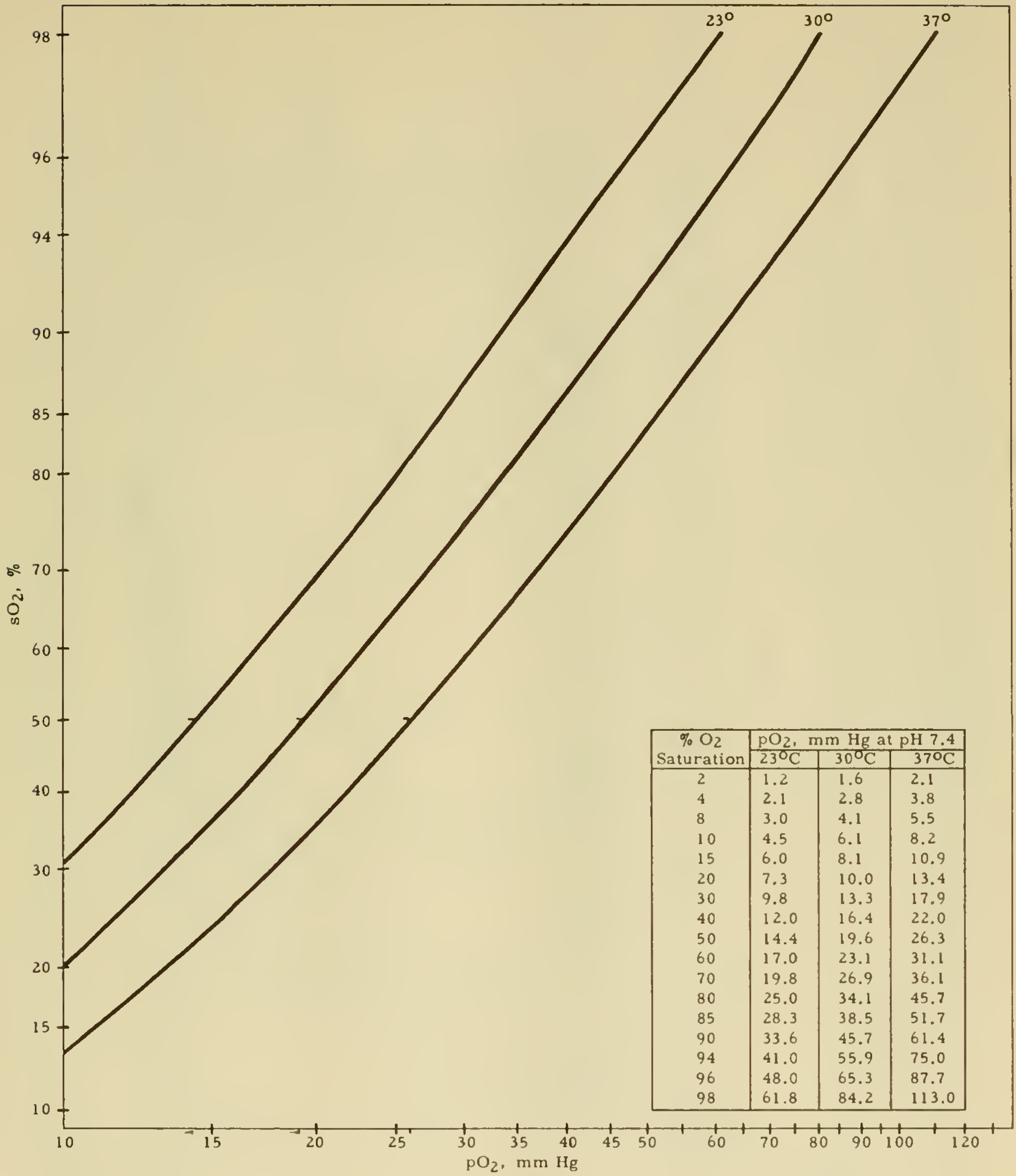
% O_2 Saturation	pO_2, mm Hg at 37°C		
	pH 7.6	pH 7.4	pH 7.2
2	1.7	2.1	2.6
4	3.0	3.8	4.6
6	4.4	5.5	6.8
10	6.5	8.2	10.5
15	8.7	10.9	13.5
20	10.7	13.4	15.5
30	14.2	17.9	22.1
40	17.5	22.0	27.1
50	20.9	26.3	32.3
60	24.7	31.1	38.2
70	28.7	36.1	44.3
80	36.3	45.7	56.2
85	41.1	51.7	63.6
90	48.7	61.4	77.2
94	59.5	75.0	92.1
96	69.7	87.7	108.0
98	89.8	113.0	139.0

Contributors: Bartels, H., and Opitz, E.

Reference: Dill, D. B., in "Handbook of Respiratory Data in Aviation," Committee on Medical Research, Washington, 1944.

71. BLOOD O_2 DISSOCIATION CURVES: MAN (Concluded)

Part II: AT VARIOUS TEMPERATURES



% O_2 Saturation	pO_2, mm Hg at pH 7.4		
	23°C	30°C	37°C
2	1.2	1.6	2.1
4	2.1	2.8	3.8
8	3.0	4.1	5.5
10	4.5	6.1	8.2
15	6.0	8.1	10.9
20	7.3	10.0	13.4
30	9.8	13.3	17.9
40	12.0	16.4	22.0
50	14.4	19.6	26.3
60	17.0	23.1	31.1
70	19.8	26.9	36.1
80	25.0	34.1	45.7
85	28.3	38.5	51.7
90	33.6	45.7	61.4
94	41.0	55.9	75.0
96	48.0	65.3	87.7
98	61.8	84.2	113.0

<u>Contributors</u>: Bartels, H., and Opitz, E.

<u>Reference</u>: Dill, D. B., and Forbes, W. H., Am. J. Physiol. <u>132</u>:685, 1941.

Oxygen dissociation is the relation between the amount of O_2 that remains chemically combined with Hb, and the O_2 tension of the blood at definite temperature and pH. Blood is exposed to O_2, CO_2, and N_2 in tonometers containing gas mixtures, and after sufficient time the O_2 content is determined. The amount of the physically dissolved O_2 is calculated from O_2 pressure and solubility, thus obtaining the amount of O_2 combined with Hb. At a definite O_2 pressure (pO_2 mm Hg), the proportion of Hb-bound O_2 (HbO_2) to the maximum binding capacity of Hb for O_2 (O_2 capacity) equals the per cent of O_2 saturation of Hb (sO_2 % of Hb): $\frac{HbO_2 \text{ (vol \%)}}{O_2 \text{ capacity (vol \%)}} \times 100 = \%\ O_2$ saturation of Hb. If per cent O_2 saturations are to be compared at different O_2 pressures, the pH for all O_2 saturations must be the same. Therefore, the pH values of the individual blood tests must be determined, and the O_2 pressure of the blood calculated according to pH value. Conversion factor for blood of man: $\log pO_2 = -0.048$ pHs.

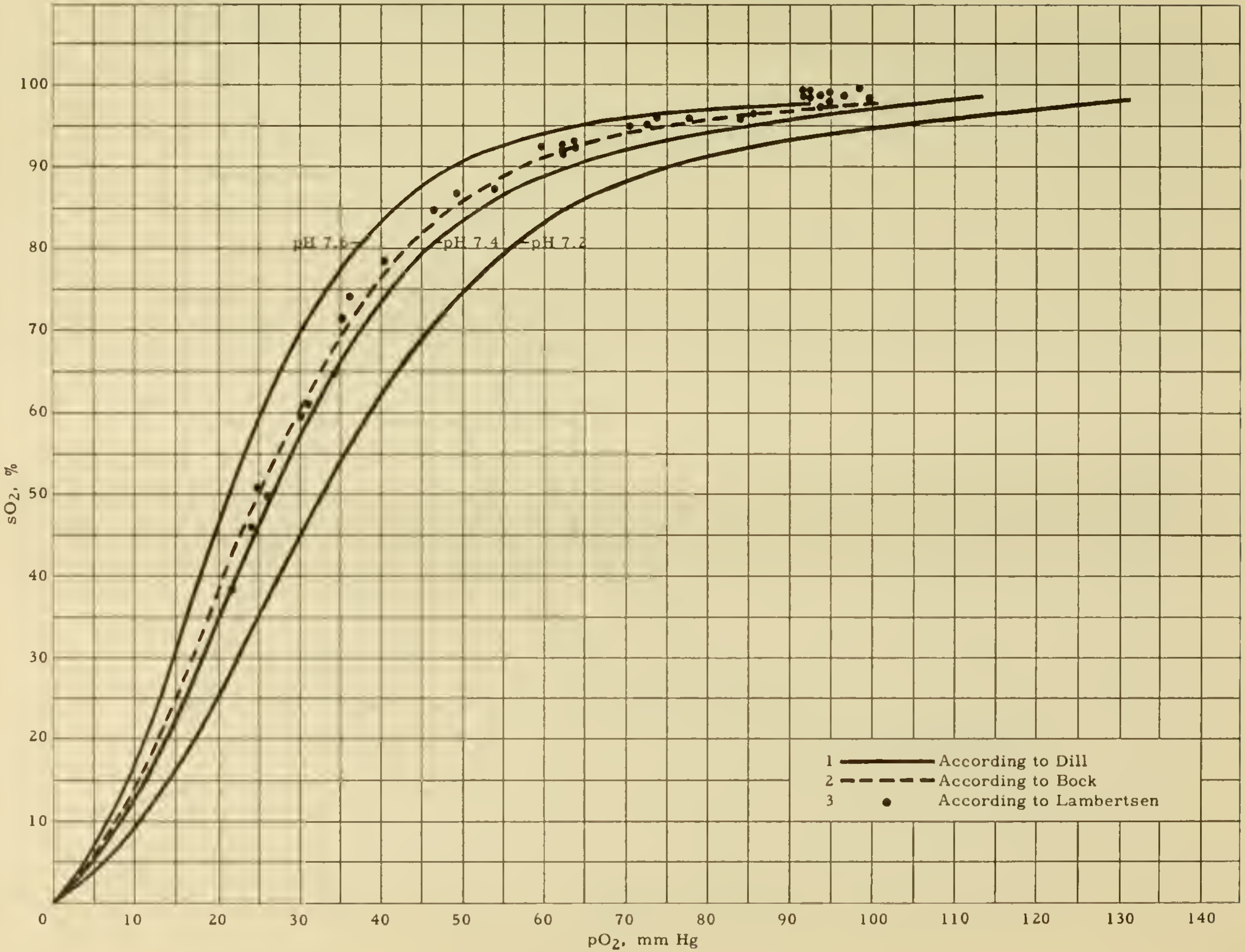
Part I: METHODS OF OBSERVATION

A position to the left of the adult dissociation curve was found for new-born children [1], that shifts to the right during the first three months of life [2, 3]. In adaptation to height for adults, there were no significant changes in the O_2 dissociation curves except for a very small shift to right [4]. A definite shift to right was seen in sickle cell anemias [5]. Anti-coagulant: H = heparin, P-O = potassium oxalate, S-F = sodium fluoride. Technique: I-Vt = in vitro, I-Vv = in vivo. Method: Bt = Barcroft tonometer [6], F = ferrocyanide modification [7] of Haldane [8], K = Kugel tonometer [9], M = manometric [10], S = Scholander [11], Sp = spectrophotometric [12], V-S = Van Slyke and Stadie [13].

	Species	Anti-coagulant	Equilibration			Oxygen Capacity		pH or pCO_2 Estimation	Reference
			Temp, °C	Technique	Method	pO_2	Method		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Man		37	I-Vt			M	pHs 7.40	14
2	Man	P-O	37.5	I-Vt	Bt	~150 mm Hg	V-S	pCO_2 40 mm Hg	15
3	Man		37	I-Vv			Sp[1]	pHs 7.40[2]	16
4	Cat[3]	P-O, S-F	37	I-Vt	K	~200 mm Hg	M	pHs 7.40	17
5	Dog		37	I-Vt			M	pHs 7.40	18
6	Sea lion	P-O	38	I-Vt			M	pCO_2 ~ 44 mm Hg	19
7	Guinea pig	H, P-O, S-F	37	I-Vt	K	~200 mm Hg	M	pHs 7.40	20
8	Rabbit	H, P-O, S-F	37	I-Vt	K	~200 mm Hg	M	pHs 7.40	20
9	Rabbit	H	38.6	I-Vt, I-Vv	Bt		M	pHs 7.40	4, 21
10	Rat, albino		38	I-Vt	Bt		F	pHs 7.40	22
11	Rat, kangaroo		37	I-Vt	Glass syringes		S	pCO_2 ~ 40 mm Hg	23
12	Cow		38	I-Vt	Bt		Barcroft's[4]	pCO_2 40-42 mm Hg	24
13	Goat[5]	P-O, S-F	38	I-Vt	Bt		M	pCO_2 ~ 50 mm Hg	25
14	Horse		38	I-Vt				pHs 7.40	26
15	Llama	H	39	I-Vt, I-Vv	Bt		M	pHs 7.40	4
16	Sheep	H	39.3	I-Vt, I-Vv	Bt		M	pHs 7.40	4
17	Vicuna	H	39 and 40[6]	I-Vt	Bt		M	pHs 7.40	4
18	Porpoise	Sodium oxalate	38	I-Vt			M	pCO_2 ~ 46 mm Hg	27

/1/ Method of Riley, et al [28]. /2/ With glass electrode, using the Henderson-Hasselbalch equation [29]. /3/ Chloralose-urethane used as anesthetic. /4/ Differential manometer. /5/ Urethane used as anesthetic. /6/ At 2.81 and 4.71 km respectively.

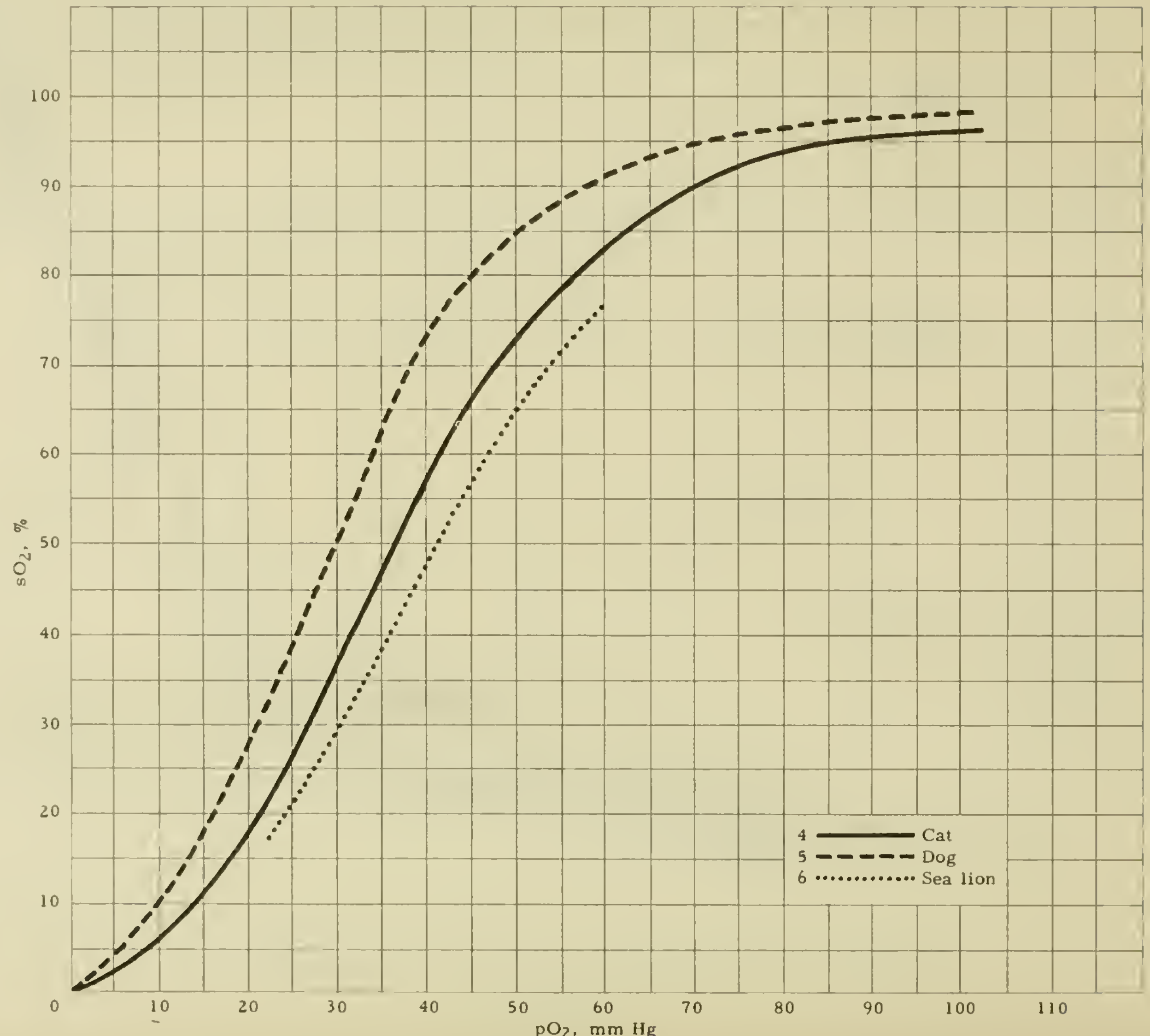
Numbers in legend refer to numbers under Part I: METHODS OF OBSERVATION.



72. BLOOD O_2 DISSOCIATION CURVES: MAMMALS (Continued)

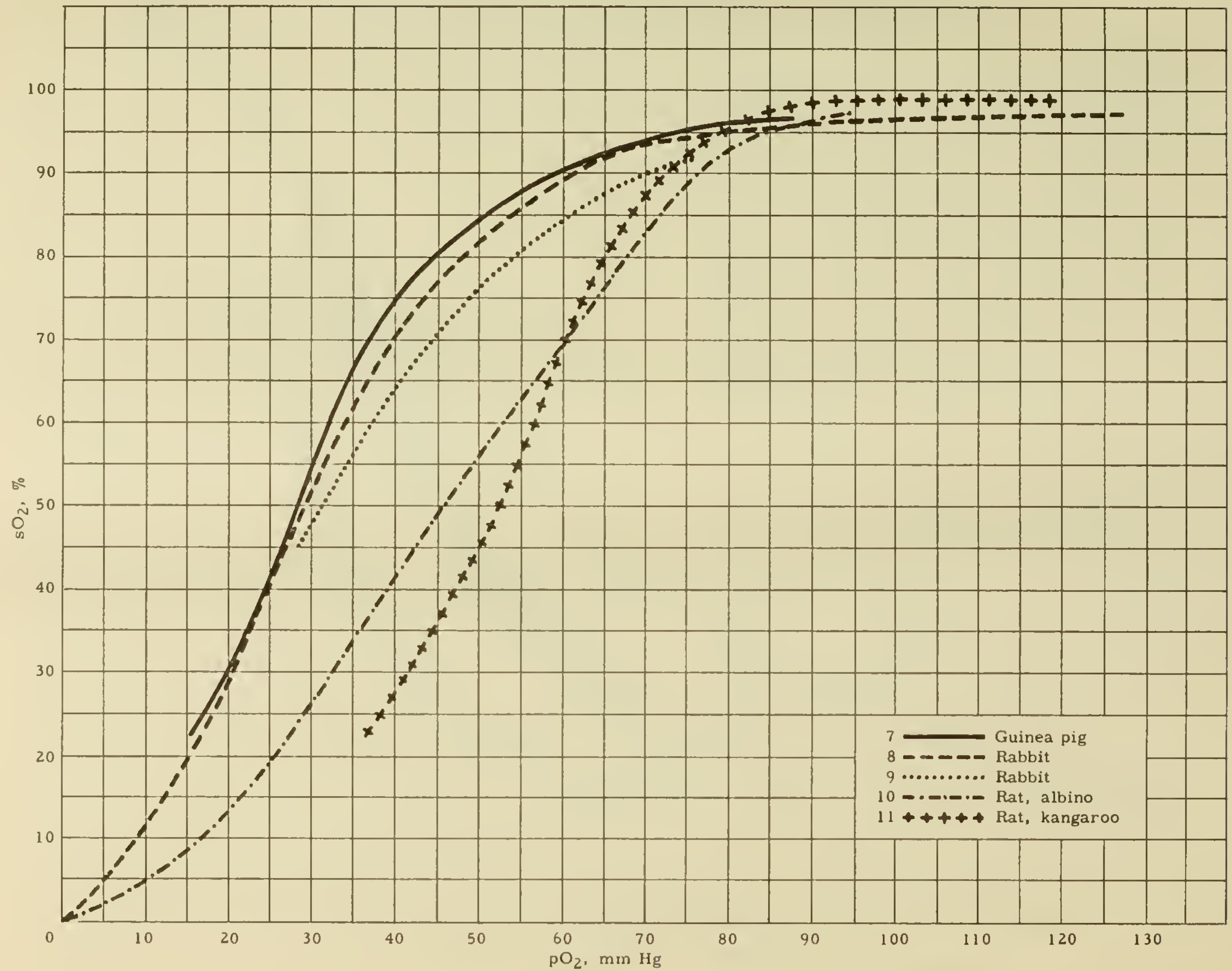
Part III: CARNIVORES

Numbers in legend refer to numbers under Part I: METHODS OF OBSERVATION.



Part IV: RODENTS

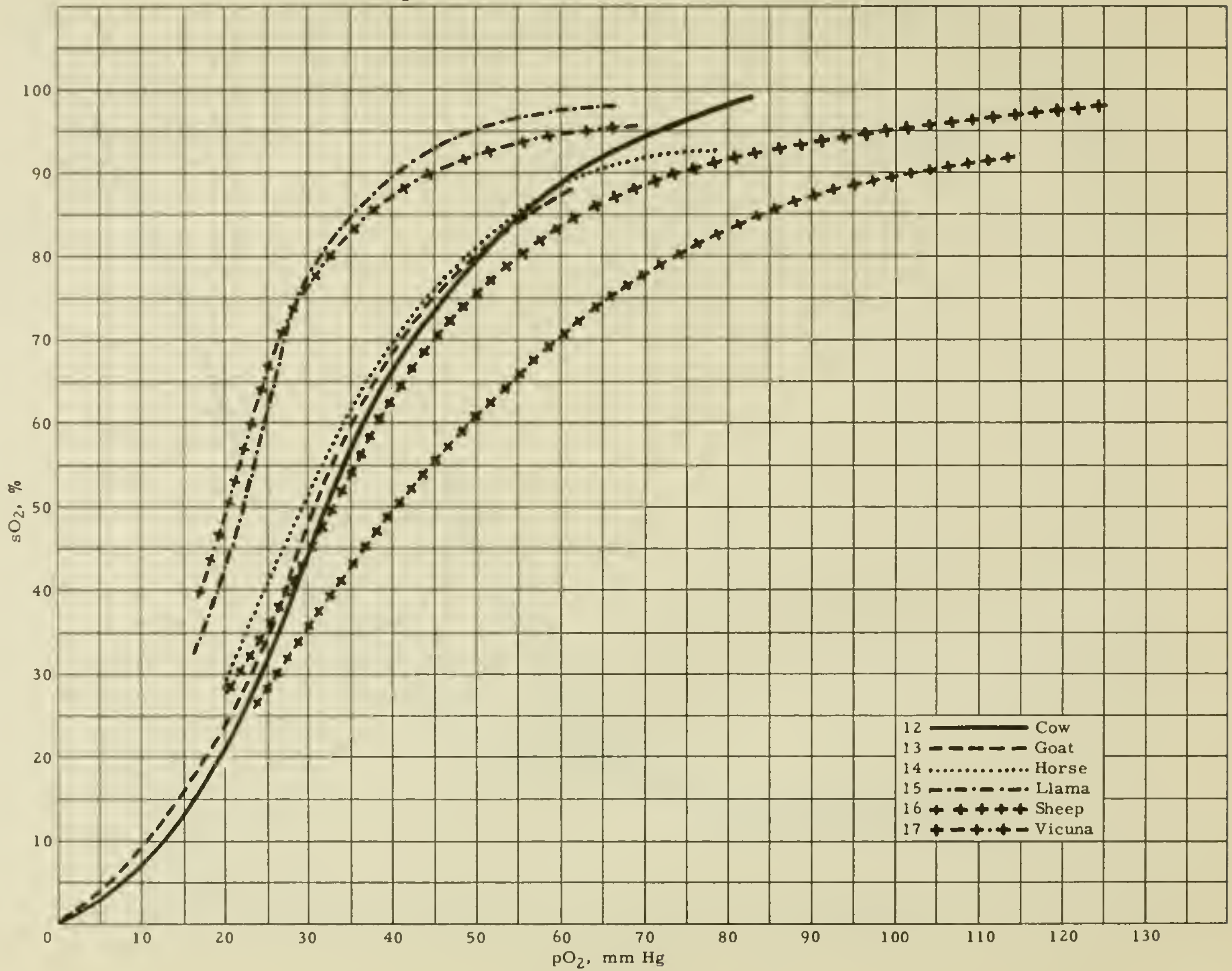
Numbers in legend refer to numbers under Part I: METHODS OF OBSERVATION.



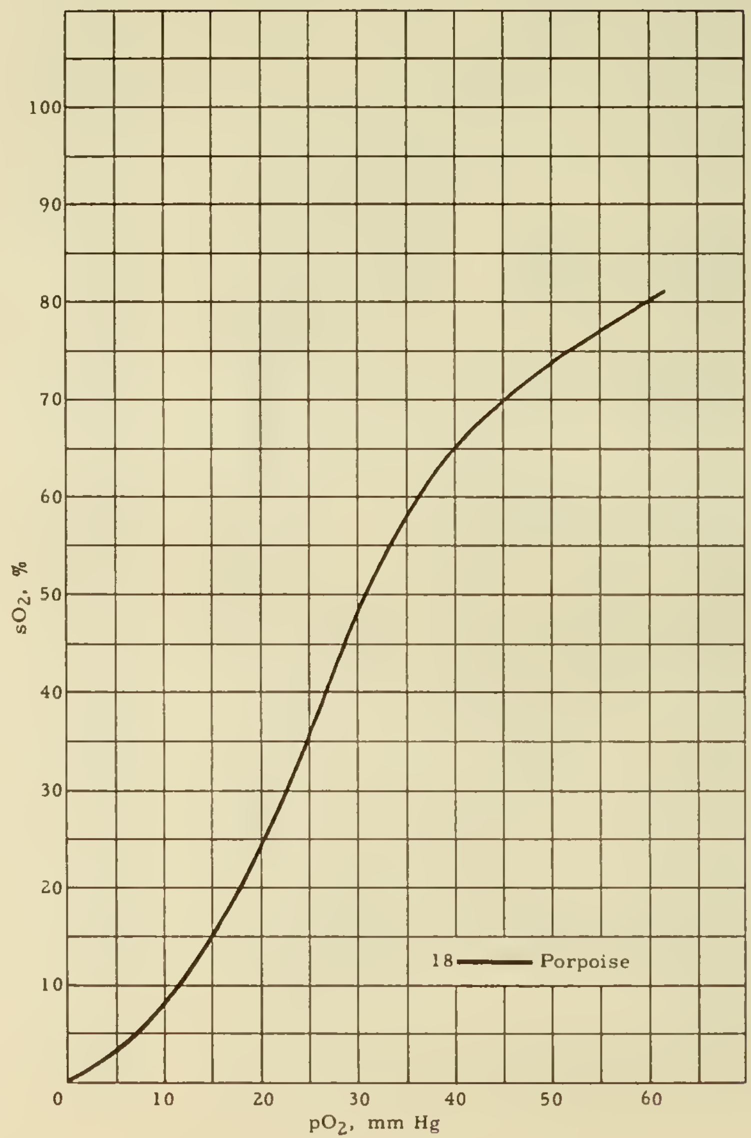
72. BLOOD O_2 DISSOCIATION CURVES: MAMMALS (Concluded)

Part V: UNGULATES

Numbers in legend refer to numbers under Part I: METHODS OF OBSERVATION.



Numbers in legend refer to numbers under Part I: METHODS OF OBSERVATION.



Contributor: Bartels, H.

References: [1] Beer, R., Bartels, H., and Raczkowski, H. A., Pflügers Arch. 260:306, 1955. [2] Beer, R., Doll, E., and Wenner, J., unpublished. [3] Morse, M., Cassels, D. E., Holder, M., O'Connell, E., and Swanson, A., J. Clin. Invest. 29:1091, 1950. [4] Keys, A. B., Hall, F. G., and Barron, E. S., Am. J. Physiol. 115:292, 1936. [5] Becklake, M. R., Griffith, S. B., McGregor, M., Goldman, H. I., and Schreve, J. P., J. Clin. Invest. 34:751, 1955. [6] Barcroft, J., "The Respiratory Function of the Blood," Part II, Haemoglobin, Cambridge University Press, 1928. [7] Maegraith, B. G., Jones, E. S., and Sculthorpe, H. H., Ann. Trop. M. Parasit., Liverp. 44:101, 1950. [8] Haldane, J. S., J. Path. Bact., Lond. 23:443, 1920. [9] Laue, D., Pflügers Arch. 254:142, 1951. [10] Peters, I. P., and Van Slyke, D. D., "Quantitative Clinical Chemistry: Methods," Baltimore: Williams and Wilkins, 1932. [11] Scholander, P. F., Flemister, S. C., and Irving, L., J. Biol. Chem. 169:173, 1947. [12] Haldane, J. S., "Methods of Air Analysis," London: Charles Griffin, 1920. [13] Van Slyke, D. D., and Stadie, W. C., J. Biol. Chem. 49:1, 1921. [14] Dill, D. B., in "Handbook of Respiratory Data in Aviation," Committee on Medical Research, Washington, 1944. [15] Bock, A. V., Field, H., Jr., and Adair, G. S., J. Biol. Chem. 59:353, 1924. [16] Lambertsen, C. J., Bunce, P. L., Drabkin, D. L., and Schmidt, C. F., J. Appl. Physiol. 4:873, 1952. [17] Bartels, H., and Lühning, I., unpublished. [18] Rahn, H., and Bahnson, H. T., WADC Tech. Rept. 53-255, 1953. [19] Florkin, M., and Redfield, A. C., Biol. Bull. 61:422, 1931. [20] Bartels, H., and Harms, H., unpublished. [21] Hall, F. G., Dill, D. B., and Barron, E. S., J. Cellul. Physiol. 8:39, 1936. [22] Jones, E. S., Maegraith, and Sculthorpe, H. H., Ann. Trop. M. Parasit., Liverp. 44:168, 1950. [23] Gjönnes, B., and Schmidt-Nielsen, K., J. Cellul. Physiol. 39:147, 1952. [24] Roos, J., and Romijn, C., J. Physiol., Lond. 92:249, 1938. [25) Barcroft, J., Flexner, L. B., Herkel, W., McCarthy, E. F., and McClurkin, T., ibid 83:215, 1935. [26] Van Slyke, D. D., Wu, H., and McLean, F., J. Biol. Chem. 56:765, 1923. [27] Green, A. A., and Redfield, A. C., Biol. Bull. 64:44, 1933. [28] Riley, R. L., Proemmel, D. D., and Franke, R. E., J. Biol. Chem. 161:621, 1945. [29] Henderson, L. J., "Blut," Dresden: Steinkopff, 1932.

73. O_2 CAPACITY OF UMBILICAL VEIN BLOOD AT VARIOUS STAGES OF PREGNANCY: MAN

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Duration of Pregnancy wk	Cases no.	O_2 Capacity vol %
	(A)	(B)	(C)
1	36	9	20.1(16.6-24.1)
2	37	9	22.0(18.5-25.1)
3	38	16	20.7(17.6-25.5)
4	39	24	19.9(17.0-24.2)
5	40	30	21.3(17.8-23.2)
6	Term	88	20.8(16.6-25.5)[1]
7	41	14	21.3(16.8-25.6)
8	42 and over	40	20.7(16.2-24.5)
9	Postmaturity	54	20.9(16.2-25.6)[2]

/1/ Mean and range for Lines 1-5. /2/ Mean and range for Lines 7,8.

Contributor: Nesbitt, R. E. L., Jr.

References: Prystowsky, H., and Eastman, N. J., Bull. Johns Hopkins Hosp. 101:45, 1957.

74. O_2 SATURATION IN BLOOD OF UMBILICAL VESSELS, NORMAL AND DIFFICULT LABOR: MAN

Spontaneous, uncomplicated delivery: all deliveries in occipito-anterior presentation and without evidence of meconium staining. Complicated delivery: forceps deliveries and cesarean sections; spontaneous deliveries in occipito-anterior presentation, with meconium staining of the amniotic fluid or other signs of asphyxia before or after delivery.

	Menstrual Age wk	Spontaneous, Uncomplicated Delivery				Complicated Delivery			
		Cases no.	Venous O_2 Saturation, %	Cases no.	Arterial O_2 Saturation, %	Cases no.	Venous O_2 Saturation, %	Cases no.	Arterial O_2 Saturation, %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	>43	30	64.5	25	30.4	22	53.4	18	26.2
2	42	33	60.4	27	33.0	26	47.9	17	19.9
3	41	52	62.6	42	34.6	38	50.7	30	25.6
4	40	39	61.3	26	36.4	28	49.2	23	27.7
5	39	28	62.9	21	39.7	11	61.4	9	34.6
6	38	20	61.8	16	30.6	7	64.9	7	43.6
7	37	14	51.9	10	28.5	3	46.0	3	13.0
8	36	3	69.0	2	47.0	3	16.7	3	10.7
9	35	2	36.5	1	30.0				
10	33	1	60.0	1	38.0				
11	31	1	74.0	1	24.0				
12	28							1	21.0
13	27	1	72.0						
14	20	1	51.0						

Contributor: Nesbitt, R. E. L., Jr.

Reference: Rooth, G., and Sjostedt, S., Acta obst. gyn. scand. 36:374, 1957.

75. O_2 PRESSURE GRADIENT BETWEEN FETAL AND MATERNAL BLOOD: MAN

Placental vessel: I-S = intervillous space, U-V = unbilical vein, U-A = unbilical artery.

	Method of Delivery	Cases no.	Placental Vessel	O_2 Capacity vol %	O_2 Content vol %	O_2 Saturation %	Estimated pO_2 mm Hg	MpO_2-FpO_2[1] mm Hg
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Cesarean	2	I-S	14.8	8.1	54.7	27.8	17.7
2			U-V	20.2	5.1	25.0	12.5	
3			U-A	20.2	3.4	16.8	8.0	
4		5	I-S	11.2	5.0	44.6	24.0	18.3
5			U-V	18.4	1.8	9.7	6.5	
6			U-A	18.4	1.1	5.9	5.0	
7	Vaginal	4	I-S	15.7	8.4	53.5	27.8	15.6
8			U-V	20.6	5.1	24.7	12.2	
9		6	I-S	16.0	8.3	51.8	26.5	14.3
10			U-V	21.9	5.2	23.7	12.2	
11		10	I-S	15.8	15.3	96.8	72.0	33.0
12			U-V	20.7	17.4	84.0	39.0	
13		12	I-S	22.4	19.2	85.7	48.0	27.0
14			U-V	21.2	10.0	47.1	21.0	
15		13	I-S	14.1	10.8	76.5	40.1	15.1
16			U-V	18.1	10.9	60.3	25.0	
17		21	I-S	15.7	10.6	67.4	34.0	20.4
18			U-V	19.3	6.6	34.1	16.0	
19			U-A	19.3	3.9	20.2	11.0	

/1/ MpO_2 = partial pressure of O_2 in maternal circulation; FpO_2 = partial pressure of O_2 in fetal circulation.

Contributor: Nesbitt, R. E. L., Jr.

Reference: Prystowsky, H., Bull. Johns Hopkins Hosp. 101:48, 1957.

76. O_2 DISSOCIATION RELATIONSHIPS OF FETAL AND MATERNAL BLOOD: MAN, COW, SHEEP

An approximate curve can be drawn for the range of values from 15-80 mm Hg pO_2, based upon the pO_2 at half saturation, but the curve is not necessarily valid above and below these pressures. The half saturation pO_2 is, therefore, a satisfactory approximation. Inflections of the curves around this point have not been investigated in sufficient detail as yet. In man, separation of hemoglobin from the corpuscle results in a decrease of half saturation pO_2 of 9 mm Hg for maternal blood and 2 mm for fetal at pH 6.8 and 37°C; this may reverse their relative positions [1]. Values in parentheses are ranges, estimate "b" or "c" of the 95% range (cf Introduction).

	Animal	No.	Age	pO_2, mm Hg[1] Half Saturation: Maternal	Fetal	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Man			31(30-35)[c2]	25(22-29)[c2]	40	2
2		1		33[3]	25[3]	40	3
3		22[4]	Term	27.27(26.37-28.17)[b5]	21.86(21.26-22.46)[b5]	pH = 7.4	4
4		22[4]	Term	29.08(28.02-30.14)[b5]	23.94(23.10-24.78)[b5]	40	4
5	Cow	3	3.5 mo gestation	34	18	43(41-45)[b]	5
6		2	5.5 mo gestation	33	23	43(41-45)[b]	5
7		7	7 and 8 mo gestation	32	20	43(41-45)[b]	5
8		6	At birth	31.5	22.5	43(41-45)[b]	5
9	Sheep		50 to 111 da	(42-49)[c]	(17-19)[c]	40(36-44)[b]	6
10		2	139 and 140 da gestation		(25-26)[c]	40(38-42)[b]	6

/1/ Temperature, 38°C. /2/ Derived from graphic approximations corrected to pCO_2 = 40. /3/ Estimated from published curve. /4/ 6 maternal, 16 fetal. /5/ Corrected for $\Delta \log pO_2 = -0.048 \, \Delta$ pH.

Contributor: Kaiser, I. H.

References: [1] McCarthy, E. F., J. Physiol., Lond. 102:55, 1943. [2] Leibson, R. G., Likhnitzky, I. I., and Sax, M. G., ibid 87:97, 1936. [3] Eastman, N. J., Geiling, E. M., and De Lawder, A. M., Bull. Johns Hopkins Hosp. 53:246, 1933. [4] Darling, R. C., Smith, C. A., Asmussen, E., and Cohen, F. M., J. Clin. Invest. 20:739, 1941. [5] Roos, J., and Romijn, C., Proc. Koninkl. Ned. Akad. Wetenschap. 43:1212, 1940. [6] Barron, D. H., Yale J. Biol. 24:169, 1951.

77. O_2 DISSOCIATION CURVES FOR FETAL BLOOD: MAMMALS

Although the following data concerning the oxygen relationships of fetal blood are somewhat sketchy and fragmentary, they represent, nevertheless, important inroads in the ultimate understanding of intra-uterine fetal environment. The reader should not be discouraged by the apparent conflicting data presented, since the several reports may not be analogous in all respects. The many enigmas in clinical obstetrics and in the selection of cases for study have undoubtedly led the several authors, despite similar objectives, to conduct different experiments. At the same time, the reader should realize that there is disagreement about the best index of fetal oxygenation. The current interest in oxygen saturations has arisen because these determinations are much easier to compute than are pO_2 values. It should be borne in mind that pO_2, pH, and pCO_2 are related variables and that a two-dimensional representation is not necessarily indicative of the true physiologic circumstances. Moreover, when the pH values are corrected to an arbitrary figure, oxygen saturation determinations lose much of their meaningfulness, for as the pO_2 decreases, so does the pH. Another problem arises from the wide normal variation encountered in both oxygen capacity and oxygen content of umbilical cord blood, as any substantial variation in oxygen capacity and content will necessarily result in great variations in the calculated percentage of oxygen saturation. Since the partial pressure of oxygen is calculated from the oxygen saturation, it is understandable that considerable sampling errors may be encountered in this work. More data are needed concerning the significance and interrelationships of the several oxygen indexes, namely, oxygen saturation of the umbilical vein and of the umbilical artery, arterio-venous difference between these two figures, oxygen reserve in the umbilical artery, and the oxygen gradient, before the true status of fetal oxygenation can be evaluated. These experimental limitations, however, should not detract from the statistical validity of the enclosed data derived from careful studies conducted in accordance with accepted physiological principles.

Contributor: Nesbitt, R. E. L., Jr.

Part I: METHODS OF OBSERVATION

Since the alkali reserve in fetal blood differs from that of the mother, and differs among species, curves showing equal CO_2 pressures may have various pH values. The affinity of infant blood of man is higher than that of adult blood [1], and therefore the pH values for fetal blood should be standardized by using the conversion factor for adult blood of man: $\log pO_2 = -0.048$ pHs (pHs = 0.1 pH units). This factor is also best used for other species [2]. Fetal age is quite important as there is a possibility of change in the dissociation curve with the increase in age of the fetus. For man, Bartels, Harms, and Harms obtained curves from 28-week-old fetuses showing a minimal shift to the left when compared with curves of older fetuses [3]. Anti-coagulant: H = heparin, P-O = potassium oxalate, S-F = sodium fluoride. Technique: I-Vt = in vitro, I-Vv = in vivo. Method: B = Barcroft [4], Bt = Barcroft tonometer [5], C = colorimetric Hb estimation, E = electrometric, K = Kugel tonometer [6], M = manometric [7], P = potentiometric [8].

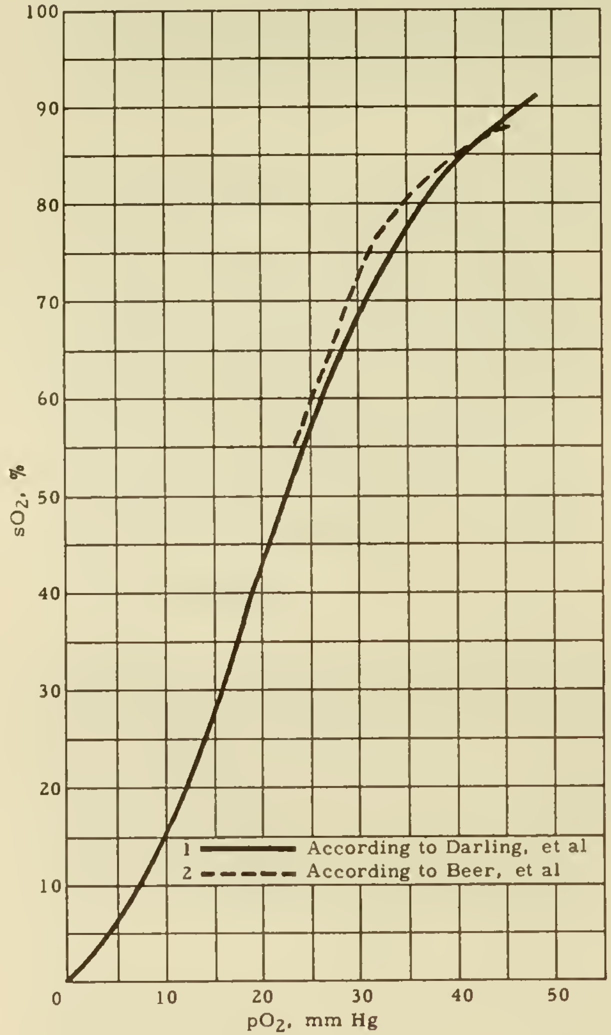
	Animal	No.	Fetal Age	Anti-coagulant	Equilibration Temp, °C	Equilibration Technique	Equilibration Method	Method of pO_2 Estimation	pH or pCO_2 Estimation	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Man	10	Full term[1]	H	37	I-Vt	Bt	M	pHs 7.40	9
2	Man	8	Full term	P-O, S-F	37	I-Vv	P	M, K, P	pHs 7.40	10
3	Cow	1	About 36 wk		38.5	I-Vt	Bt	B	pCO_2 43-45 mm Hg	11
4	Goat	20	At birth and 18 da after birth	P-O	38	I-Vt	Bt	M	pCO_2 50 mm Hg	12
5	Rabbit		30 da		38	I-Vt	Bt	M, C[2]	E[3]	13
6	Sheep	6	60-120 da and 120-150 da	H, S-F	38	I-Vt	Bt	M	pCO_2 40 mm Hg	14

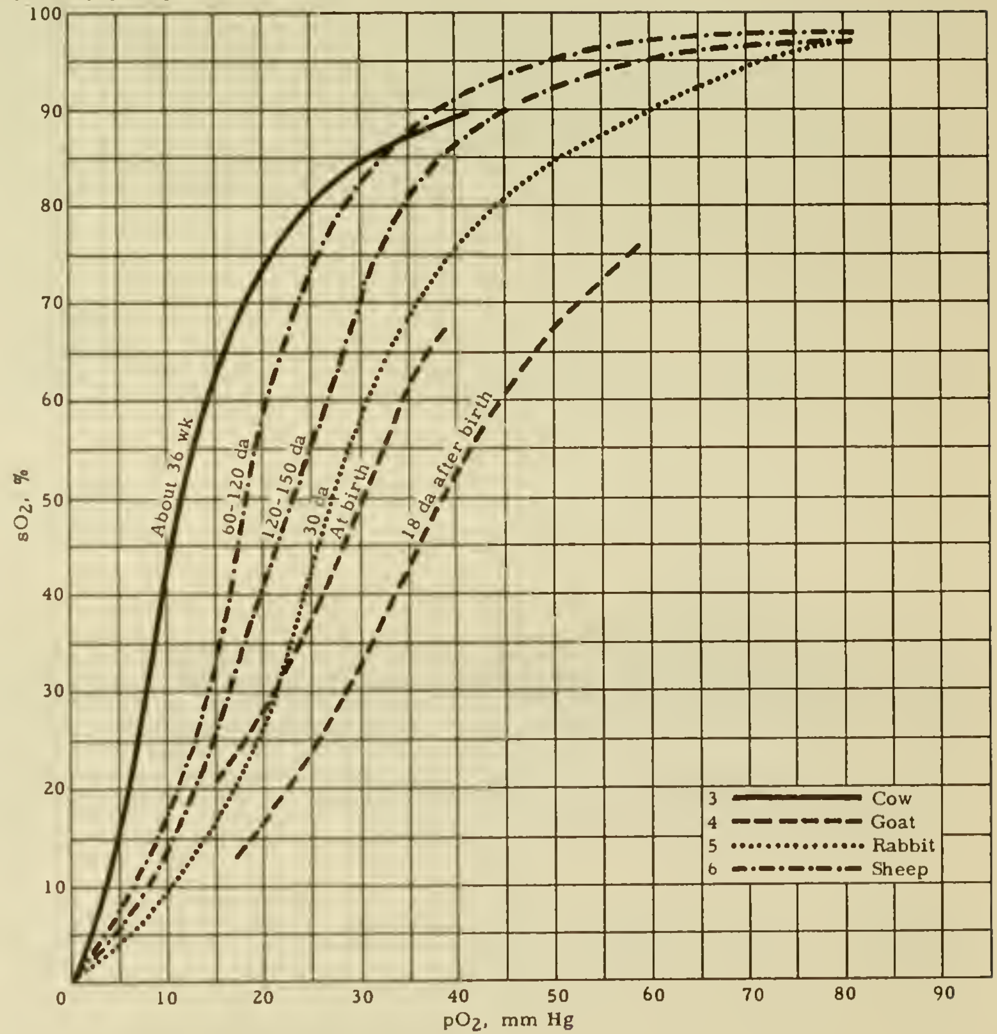
/1/ 8 cases full term and 2 cases before term; no significant difference between the two groups. /2/ Calculated on basis of C. /3/ Estimated.

Part II: MAN

Part III: COW, GOAT, RABBIT, SHEEP

Numbers in legend refer to numbers under Part I: METHODS OF OBSERVATION.





Contributors: (a) Bartels, H., (b) Kaiser, I. H., (c) Barron, D. H.

References: [1] Eastman, N. J., Geiling, E. M., and De Lawder, A. M., Bull. Johns Hopkins Hosp. 53:246, 1933. [2] Bartels, H., and Harms, H., unpublished. [3] Bartels, H., Harms, M. L., and Harms, H., unpublished. [4] Barcroft, J., J. Physiol., Lond. 37:12, 1908. [5] Barcroft, J., "The Respiratory Function of the Blood," Part II, Haemoglobin, Cambridge: University Press, 1928. [6] Lave, D., Pflüger's Arch. 254:142, 1951. [7] Van Slyke, D. D., and Neill, J. M., J. Biol. Chem. 61:523, 1924. [8] Bartels, H., Pflüger's Arch. 254:107, 1951. [9] Darling, R. C., Smith, C. H., Asmussen, E., and Cohen, F. M., J. Clin. Invest. 20:739, 1941. [10] Beer, R., Bartels, H., and Raczkowski, H. A., Pflüger's Arch. 260:306, 1955. [11] Roos, J., and Romijn, C., J. Physiol., Lond. 92:249, 1938. [12] Barcroft, J., et al, ibid 83:192, 1934. [13] Barron, D. H., and Meschia, G., Sympos. Quant. Biol. 19:93, 1954. [14] Barron, D. H., Yale J. Biol. 24:169, 1951.

Definitions of acid, base, and buffer base given on Page 95, Table 80, Part I.

Part I: CONSTANTS, FACTORS, AND FORMULAS

Temperature corrections for pH measurements (Lines 12-16) have been used in an attempt to reduce to a comparable basis some of the experimental values cited in Parts II-IV.

	Factor	Value	Unit	Constant, Formula, or Method	Reference
	(A)	(B)	(C)	(D)	(E)
1	Volume, at 0°C and 760 mm Hg, occupied by 1 g M of O_2. In the case of hemoglobin, grams may be related to O_2 capacity.	22.41	Liter	1 mM Hb O_2 = 22.4 ml. (STP)	1
2	Volume, at 0°C and 760 mm Hg, occupied by 1 g M of CO_2	22.26	Liter	CO_2, mM/L = $\frac{CO_2 \text{ volumes per cent}}{2.226}$	1
3	Standard body temperature, man	37	Degrees Centigrade		2
4	Solubility factor of CO_2 in normal human plasma at 37°C	0.0314	mM/L per mm CO_2 pressure	For plasma or serum water = 940 g/L	3-5
5	Apparent first dissociation constant, carbonic acid in human serum or plasma, 37°C	6.10		$pK'_1 = pH - \log \frac{CO_2 - (0.0314)\, pCO_2{}^1}{0.0314\, pCO_2}$	6-8
6	Factor by which whole-blood CO_2 content should be multiplied to obtain plasma CO_2 content, when hemoglobin content (or hematocrit value), pH, and O_2 saturation are given. Normally Hb = 9 mM/L or 15 g/100 ml or 20.2 volume %, pH = 7.40, O_2 saturation = 100%, and f = 1.217	About 1.217 in normal arterial blood		$(CO_2)p = f(CO_2)_b$	9, 10
7	Buffer base, $(BB)_b$, or cation and equivalent sum of blood bicarbonate, hemoglobin, and plasma protein anions. Normally $(HCO_3^-)_b$ = 21.0 m Eq/L, oxygenated blood Hb = 9 mM/L, plasma protein = 39.8 g/L, pH = 7.40, then $(BB)_b$ = 21.0 + 9.0 (2.01) + 39.8 (0.24) = 49.1 mEq/L	About 49.1 in normal arterial blood	mEq/L	$(BB)_b = (HCO_3^-)_b + Hb(f_1) +$ plasma protein (f_2)	11
	Temperature coefficients, per °C increase, at 37°C:				
8	CO_2 solubility factor	-0.0007	mM/L per mm of CO_2 pressure		12
9	Plasma carbonic acid pK'_1	-0.005			13
10	pH of whole blood or true plasma	-0.015			14
11	pH of separated plasma	-0.012			14

12	Temperature corrections for pH measurements: Correction to pH of separated plasma read at 38°C, centrifuged at average room temperature of 25°C, to obtain pH of true plasma at 37°C	-0.025		Change pH true plasma 37° to 25° = (-0.015) x (-12) = +0.180; Change pH separated plasma 25° to 38° = (-0.012) x (+13) = -0.155; Therefore, observed pH reads too high by +0.025	15
13	Correction to colorimetric pH read at 20°C on separated plasma to get pH at 38°C	-0.23			16, 17
14	Line 14 (correction) and Line 15 (correction) combined to get pH of true plasma at 37°C	-0.255			15-17
15	Correction to colorimetric pH read at 20°C on separated serum to get pH at 38°C	-0.30			17
16	Line 14 (correction) and Line 17 (correction) combined to get pH of true serum at 37°C	-0.325			15, 17
17	mEq/L $\rightleftarrows$ mg/100 ml, conversion equation			$\text{mEq/L} = \frac{(\text{mg/100 ml}) \times 10 \times \text{valence}}{\text{g-ionic wt}}$	18

/1/ Henderson-Hasselbalch equation.

Contributors: Singer, R. B., and Hastings, A. B.

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Definitions of acid, base, and buffer base given on Page 95, Table 80, Part I.

Part II: ARTERIAL BLOOD

Diagram showing ionic patterns of arterial blood appears on Page 96, Table 80, Part II. Hemoglobin concentration assumed to be 20 mM/L RBC; one mM (single Fe-atom structure, molecular weight 16,500) combines with 22.4 ml of O_2, STP when saturated. Handling of blood [1]: The four digits in the code number refer, successively, to anticoagulant, method of drawing blood, storage of sample, and centrifugation. Anticoagulant: (1) dry potassium oxalate; (2) mixture of dry oxalate and fluoride; (3) dry heparin; (4) heparin in 0.9% NaCl. Drawing of blood: (1) oiled syringe; (2) syringe with dry anticoagulant; (3) syringe with dead space filled with heparin-saline solution. Storage (chilled to less than 5°C): (1) under oil; (2) over mercury; (3) in syringe. Centrifugation: (1) no centrifugation; (2) special stoppered tube. Abbreviations: CpH = calculation of pH by means of Henderson-Hasselbalch equation (cf Part I, Line 5); G = glass electrode, whole blood [2]; R = room temperature; X = gasometric Van Slyke, tonometer saturation with O_2 [1]; Y = gasometric Van Slyke, tonometer saturation with corrections [3]; Z = spectrophotometer, as oxyhemoglobin or cyanmethemoglobin [4, 5]; I = interpolated CO_2 dissociation curve [6]; C = calculation of CO_2 pressure by means of Henderson-Hasselbalch equation (cf Part I, Lines 4 and 5). Average adult arterial O_2 saturation = 98%. Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Age	No. and Sex	Handling of Blood	pH			Hemoglobin		CO_2 Content		CO_2 Pressure		Buffer Base[5] mEq/L	Reference
				Method	Observed	Adjusted[1]	Method[2]	Concentration mM/L	Whole Blood[3] mM/L	Plasma[4] mM/L	Method	Blood or Plasma mm Hg		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)
1	8-15 yr	11♂	3122	CpH	7.38	7.38	X	8.2	21.5	25.6	I	40.4(33.0-47.8)	46.3	7
2	16-48 yr	35♂	3122	CpH	7.39	7.39	X	9.0	22.5	27.4	I	42.5(35.4-49.6)	48.5	7
3	18-29 yr	50♂	11?1	G[6]	7.42(7.39-7.44)	7.43	X	9.3(8.1-10.5)	21.6(20.4-22.8)	26.6	C	37.0	48.4	8
4	18-39 yr	36♂	4231	G, R	7.39(7.34-7.44)	7.39	Z	8.7(7.7-9.7)	22.5(20.7-24.3)	27.1	C	42.0	48.6	9
5	21-52 yr	10♂	2311, 4231	G?	7.42(7.40-7.44)	7.42	X	8.3(7.1-9.5)	22.2(20.8-23.6)	26.7	C	39.0(37.4-40.6)	48.3	10
6	48-76 yr	14♂	3122	CpH	7.38	7.38	X	8.9	22.1	26.8	I	42.8(38.0-46.6)	47.4	7
7	50-77 yr	22♀	4231	G, R	7.42(7.34-7.50)	7.42	Y	7.8(6.2-9.4)	21.1(17.7-24.5)	25.0	C	36.3(28.3-44.3)	45.3	11
8	50-81 yr	27♂	4231	G, R	7.42(7.36-7.48)	7.42	Y	7.7(5.7-9.7)	21.5(18.1-24.9)	25.4	C	37.0(28.8-45.2)	45.6	11
9	Adult	12♂	3122	CpH	7.39(7.34-7.44)	7.39	X	9.0(7.8-10.2)	21.9(20.9-22.9)	26.4[7]	I	41.0(38.2-43.8)	48.5	12
10	Adult	10♂	3122	CpH	7.38(7.34-7.42)	7.38	X	8.9	22.1(20.5-23.7)	26.5	I	42.8	48.0	13
11	Adult	106♂	3122	CpH	7.37(7.31-7.43)	7.37			22.2(20.2-24.2)	26.9	I	43.3		13
12	Adult	18♂	3121	CpH	7.38(7.37-7.39)	7.38				27.0[7]	I	43.1(40.1-46.1)		14

/1/ Values for pH adjusted to temperature of 37°C in accordance with Lines 10, 11, and 12-16, Part I. /2/ Oxygen capacity of hemoglobin: Gasometric determinations of hemoglobin by saturation with oxygen or carbon monoxide in a tonometer may give results 1-2% high because of drainage errors, and also because of conversion of a small amount of unidentified inactive CO-combining compound to an active form when the blood stands 1/2 to 2 hours. Most older determinations of oxygen saturation with O_2 are thus too low by 1-3%. [15] /3/ Method: gasometric, manometric Van Slyke (later 1 factor) [16]. /4/ Calculated from whole blood CO_2 content (cf Part I, Line 6). /5/ Calculated by method in Part I, Line 7. /6/ At 38°C. /7/ Not calculated; actual value.

Contributors: Singer, R. B., and Hastings, A. B.

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Hemoglobin concentration assumed to be 20 mM/L RBC; one mM (single Fe-atom structure, molecular weight 16,500) combines with 22.4 ml of O_2, STP when saturated. Handling of blood [1]: The four digits in the code number refer, successively, to anticoagulant, method of drawing blood, storage of sample, and centrifugation. Anticoagulant: (1) none used (serum sample); (2) dry potassium oxalate; (3) mixture of dry oxalate and fluoride; (4) heparin in 0.9% NaCl. Drawing of blood: (1) oiled syringe; (2) syringe with dry anticoagulant; (3) syringe with dead space filled with heparin-saline solution; (4) oil tube. Storage (at room temperature): (1) under oil; (2) over mercury; (chilled to less than 5°C): (3) under oil; (4) in syringe. Centrifugation: (1) no centrifugation; (2) oil tube; (3) special stoppered tube; (4) tube, under paraffin. Abbreviations: C = calculated; G = glass electrode, whole blood [2]; H = hydrogen electrode, serum or plasma [3]; P = colorimetric, plasma [4]; S = colorimetric, serum [5]; O = gasometric, manometric Van Slyke (original i factor) [6]; I = gasometric, manometric Van Slyke (later i factor) [7]; V = gasometric, volumetric Van Slyke [1]. Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Age	No. and Sex	Blood	Handling of Blood	pH Method	pH Observed	pH Adjusted[1]	Hemoglobin Concentration[2, 3] mM/L	Oxygen Saturation[4] %	CO_2 Content Method	CO_2 Content Plasma mM/L	CO_2 Pressure[5] mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
1	1-9 da	40♂, ♀	J	1112	S	7.400(7.322-7.478)[6]	7.375	10.3	87	O	23.6(19.7-27.5)[7]	37.7	8
2	16-34 yr	30♀[8]	A	1112	H	7.405(7.355-7.455)[6]	7.380			I	27.3(24.5-30.1)	42.6	9
3	20-39 yr	6♂	A	1112	S	7.710(7.660-7.760)[9]	7.385				28.3(23.7-32.9)	44.4	10
4	21-52 yr	10♂	M	3331, 4241	G	7.390(7.370-7.410)	7.390	8.3	72	I	28.6[10]	45.7	11
5	22-31 yr	4♀	A	1112	S	7.685(7.665-7.705)[9]	7.360			I	27.8(27.0-28.6)	46.0	10
6	Young adult	8♀	A	11?2	C		7.380			I	27.7	44.1[11]	12
7	Adult	7♂	A	3124	H, P	7.410(7.356-7.464)[6]	7.385			I	30.8(26.6-35.0)[12]	48.3	13
8	Adult	21♂	A	2113	P	7.585(7.513-7.657)[9]	7.330	9.3	55	O	30.9(27.7-34.1)[13]	54.6	14
9	Adult	74♂	A	1112	S	7.675(7.607-7.753)[9]	7.340				29.5(26.4-32.6)	51.0	15
10	Adult	27♂	A	1412				9.2	70	V	23.7(20.7-26.7)[14]		16
11	Adult	60♂	A	??11				8.8	68		24.0[14]		17

/1/ Values for pH adjusted to temperature of 37°C in accordance with Lines 10, 11, and 12-16, Part I. /2/ Method: gasometric Van Slyke, tonometer saturation with O_2 [1]. /3/ Oxygen capacity of hemoglobin: Gasometric determinations of hemoglobin by saturation with oxygen or carbon monoxide in a tonometer may give results 1-2% high because of drainage errors, and also because of conversion of a small amount of unidentified inactive CO-combining compound to an active form when the blood stands 1/2 to 2 hours. Most older determinations of oxygen saturation with O_2 are thus too low by 1-3%. [18] /4/ Method: gasometric, manometric apparatus [1], except for Line 10. /5/ CO_2 pressure at 37°C calculated from adjusted pH and CO_2 content by the Henderson-Hasselbalch equation (cf Part 1, Line 5). /6/ At 38°C. /7/ Whole blood CO_2 content = 19.1 mM/L. /8/ Postpartum, 1-7 months. /9/ At 20°C. /10/ Calculated from whole blood CO_2 content of 24.0 (22.8-25.2) mM/L. /11/ Derived from interpolated CO_2 dissociation curve [19]. /12/ Whole blood CO_2 content = 26.2(22.4-30.0) mM/L. /13/ Whole blood CO_2 content = 26.1(23.5-28.7) mM/L. /14/ Values given are for whole blood CO_2 content.

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References: [1] Peters, J. P., and Van Slyke, D. D., "Quantitative Clinical Chemistry," vol II, 1st ed., Baltimore: Williams and Wilkins Co., 1932. [2] Dole, M. W., "The Glass Electrode," New York, 1941. [3] Van Slyke, D. D., Hastings, A. B., Murray, C. D., and Sendroy, J., Jr., J. Biol. Chem. 65:701, 1925. [4] Cullen, G. E., ibid 52:501, 1922. [5] Myers, V. C., Muntwyler, E., Binns, D., and Danielson, W. H., ibid 102:19, 1933. [6] Van Slyke, D. D., and Neill, J. M., ibid 61:523, 1924. [7] Van Slyke, D. D., and Sendroy, J., Jr., ibid 73:127, 1927. [8] Marples, E., and Lippard, V. W., Am. J. Dis. Child. 44:31, 1932. [9] Nice, M., Mull, J. W., Muntwyler, E., and Myers, V. C., Am. J. Obst. 32:375, 1936. [10] Cullen, G. E., and Earle, I. P., J. Biol. Chem. 83:545, 1929. [11] Cournand, A., Riley, R. L., Breed, E. S., Baldwin, E. de F., and Richards, D. W., Jr., J. Clin. Invest. 24:106, 1945. [12] Kydd, D. M., J. Biol. Chem. 91:63, 1931. [13] Van Slyke, D. D., and Sendroy, J., Jr., ibid 79:781, 1928. [14] Cullen, G. E., and Robinson, H. W., ibid 57:533, 1923. [15] Earle, I. P., and Cullen, G. E., ibid 83:539, 1929. [16] Goldschmidt, S., and Light, A. B., Am. J. Physiol. 73:127, 1925. [17] Lennox, W. G., Arch. Int. M. 46:630, 1930. [18] Roughton, F. J., Am. J. Physiol. 142:708, 1944. [19] Eisenman, A. J., J. Biol. Chem. 71:611, 1926-27.

Definitions of acid, base, and buffer base given on Page 95, Table 80, Part I.

Part IV: CUTANEOUS BLOOD

Cutaneous blood equivalent to arterial in acid-base properties [1]. Blood from fingertip of warmed hand, collected and analyzed by microtechnique of Shock and Hastings [2]. Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Age	No. and Sex	pH[1]	RBC Volume %	CO_2 Content: Whole Blood mM/L	CO_2 Content: Plasma[2] mM/L	CO_2 Pressure[3] mm Hg	Buffer Base[4] mEq/L	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	4-6 da[5]	27♂, ♀	7.420(7.314-7.526)	50.8(50.7-50.9)	18.2(14.8-21.6)	22.8	34.2(26.8-41.6)	47.1	3
2	4-6 da[6]	18♂, ♀	7.380(7.262-7.498)	50.1(50.0-50.2)	15.3(10.7-19.9)	19.0	31.1(22.3-39.9)	43.1	3
3	17-22 yr	123♂	7.415(7.350-7.480)	46.6(44.4-48.8)	22.9(20.5-25.3)	28.0	41.2(34.1-48.3)	50.5	4
4	18-28 yr[7]	39♂	7.415(7.362-7.468)	47.5(41.8-53.2)	22.3(19.9-24.7)	27.4	40.3(33.0-47.6)	50.1	5
5	18-28 yr[8]	8♂	7.370(7.324-7.416)	46.6(42.4-50.8)	21.9(21.1-22.7)	26.8	43.5(37.9-49.1)	48.1	5
6	18-28 yr[7]	17♀	7.430(7.380-7.480)	41.0(35.2-46.8)	21.9(19.1-24.7)	26.1	37.1(32.5-41.7)	48.4	5
7	18-28 yr[8]	7♀	7.390(7.360-7.420)	38.0(35.0-41.0)	21.9(19.9-23.9)	26.0	40.4(37.5-43.3)	46.9	5
8	40-49 yr	10♂	7.400(7.360-7.440)	47.8(34.4-61.2)	22.6(19.4-25.8)	27.8	42.2(34.0-50.4)	50.0	6
9	50-59 yr	26♂	7.395(7.323-7.467)	44.1(36.9-51.3)	22.2(18.6-25.8)	26.8	41.2(32.2-50.2)	48.7	6
10	60-69 yr	54♂	7.395(7.348-7.442)	44.8(38.7-50.9)	22.3(18.0-26.6)	27.0	41.5(32.7-50.3)	49.0	6
11	70-79 yr	45♂	7.385(7.312-7.458)	43.4(37.1-49.7)	22.3(19.4-25.2)	26.8	42.0(34.7-49.3)	48.5	6
12	80-89 yr	17♂	7.385(7.307-7.463)	41.5(35.7-47.3)	22.2(17.8-26.6)	26.4	41.5(33.1-49.9)	47.9	6

/1/ Observed at 38°C but adjusted to 37°C by adding 0.015 (cf Part I, Line 10). /2/ Calculated from whole blood CO_2 content (cf Part I, Line 6). /3/ Calculated from Henderson-Hasselbalch equation with constants from Part I, Lines 4 and 5. /4/ Calculated by method in Part I, Line 7. /5/ Breast-fed infants. /6/ Infants on evaporated milk formula. /7/ Subjects seated and at rest; samples drawn at any time of day without control of previous activity. /8/ Subjects studied by successive daily samples drawn before breakfast and after one-half hour of physical rest.

Contributors: Singer, R. B., and Hastings, A. B.

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Part V: SUMMARY: BLOOD, ADULTS

Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Blood	No. and Sex	pH: Blood or Plasma	pH: Colorimetric	Hematocrit Value[1] %	CO_2 Content: Whole Blood mM/L	CO_2 Content: Whole Blood vol %	CO_2 Content: Plasma mM/L	CO_2 Content: Plasma vol %	CO_2 Pressure mm Hg	Whole Blood Buffer Base mEq/L
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
1	Arterial[2, 3]	153-277♂	7.39(7.34-7.44)			22.2(20-24)	49.5(45-53)	26.9(25-29)[4]	60.0(56-64)[4]	41.6(35-47)	48.4(46-52)
2	Venous	118-125♂	7.35(7.28-7.42)			24.4(21-28)	54.4(47-62)	29.6(26-33)	66.0(58-73)		
3		42♀	7.38(7.31-7.45)					27.5(25-32)	61.2(56-71)		
4	Cutaneous	180♂		7.41(7.35-7.47)	46.9(42-52)	22.7(20-25)	50.5(45-56)			41.3(34-48)	50.1(47-53)
5		24♀		7.42(7.36-7.48)	40.1(34-46)	21.9(19.5-24.5)	48.8(43-55)			38.1(33-43)	48.0(45-51)

/1/ Sitting position. /2/ Hemoglobin content (recumbent position) = 8.95(7.7-10.3) mM/L or 15.0(13-17) g/100 ml. /3/ RBC CO_2 content (calculated, in part, from whole blood CO_2 content) = 16.4(14.5-18.5) mM/L or 36.5(32-41) vol %. /4/ Calculated, in part, from whole blood CO_2 content.

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Representative control values given for arterial, cutaneous, or venous blood, and for alveolar CO_2 pressure. Conditions underlined are the factors varied. Change from control value due to physiological variable indicated by +, -, or 0, with actual value for amount of change given where data are available. Control value of reference series is not always the same as the control value in table. Abbreviations: R = reclining; S = sitting; St = standing; Sp = supine; B = basal; 1/2 H-R = 1/2 hour rest; B-R = bed rest; S-R = short rest; U = uncontrolled; P-I = premature infant; F-I = full-term infant; N-C = normal children; A-P = to age of puberty; Sl = sleeping; S-D = standard deviation; B-M = before menstruation; F-M = after menstruation; A-C = antecubital; I-J = internal jugular; E-J = external jugular; F = femoral; D-H = dorsal hand; A = arterial; C = cutaneous; V = venous.

	Control or Factor Varied	Conditions of Observation: Posture	Age	Sex	Time	Activity	Other	Subjects no.	Hb mM/L	Adjusted pH	Whole Blood CO_2 mM/L	Adjusted pCO_2 mm Hg	Calc. $(BB)_b$ mEq/L	Alveolar Air: Subjects no.	pCO_2 mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
							Arterial Blood									
1	Control	Sp	15-50 yr	♂	AM	B		259	9.0[1]	7.39	22.2	41.6	48.4	40	42.9	B-F,H-M,a b;N,O,1
2	Posture	R	Adult	♂ or ♀						?	?	-0.8	+		-0.8	B-D,J-M,O 2
3		S	Adult	♂ or ♀				4[2]	+0.3[3]	?	?	-2.7	+0.2[4]		-2.7	B-D,J-M,O, 2;H,1,3
4		St	Adult	♂ or ♀				16[2]	+0.6	?	?	-3.7	+0.4[4]		-3.7	B-D,J-M,O, 2;H,I,4
5	Age	Sp	3-45 da	♂ or ♀	Day		P-I	12	-0.5[5]	-0.09	-6	-4	-8			B-D,G,H, J-M,5;1,6
6		Sp	0-13 da	♂ or ♀	Day		F-1		+1.8	?	-	-	-			B-D,G,J-M, a,b;1,6
7		Sp	2-13 wk	♂ or ♀	Day		F-I		-0.6	?	-	-	-			B-D,G,J-M, a, b;1,6
8		Sp	3 mo-2 yr	♂ or ♀	Day		F-1		-1.9	?	-	-	-			B-D,G,J-M, a,b;I,6
9		Sp	2-6 yr	♂ or ♀	Day		N-C		-1.5	?	-	-	-			B-D,G,J-M, a,b;I,6
10		Sp	8-15 yr	♂ or ♀	Day	B	A-P	11	-0.9[6]	0	-1	-2.4	-2	50[7]	-2.4	B-H,J-M,7; I,6;N,O,1
11		Sp	50-81 yr	♂	Day	1/2 H-R		41	-0.8	+0.02	-0.4	-1.5	-2			B-F,H-M,8
							Cutaneous Blood									
12	Control	S	16-28 yr	♂	8-9 AM	1/2 H-R		8	9.3[3]	7.37	21.9	43.5	48.1	40[8]	42.9	B-F,H-M,9; N,O,1
13	Sex	S	16-28 yr	♀	8-9 AM	1/2 H-R		7	-1.7[3]	+0.02	0	-3.1	-1.2	32[8]	-2.1	B-F,H-M,9; N,O,1
14	Time of day	S	16-28 yr	♂	9 AM-5 PM	U		39	+0.2[3]	+0.04	+0.4	-3.2	+2.0			B-F,H-M,9
15		Sp	Adult	♂	10 AM-4 PM	B-R		1	±	+0.02	+2	±	+2			B-F,H-M, 10
16		Sp	Adult	♂	12 PM-6 AM	B-R	Sl	1	±	-0.03	+2	+8	0	6[8]	+6.2	B-M,10;N, O,11

/1/ Value for 153 subjects. /2/ For hemoglobin only. /3/ Calculated from hematocrit value, assuming hemoglobin concentration in the RBC to be 20 mM/L. /4/ Calculated from the change in hemoglobin concentration by the formula $\Delta(BB)_b = 0.6\Delta(Hb)$, for average pCO_2 and pH. /5/ Change assumed from known variation of hemoglobin with age. /6/ Change for subjects 6-14 yr old. /7/ Average age = $11\frac{1}{2}$ yr. /8/ Posture of subjects, supine; activity, basal.

Definitions of acid, base, and buffer base given on Page 95, Table 80, Part I.

Part VI: PHYSIOLOGICAL VARIABILITY (Concluded)

Representative control values given for arterial, cutaneous, or venous blood, and for alveolar CO_2 pressure. Conditions underlined are the factors varied. Change from control value due to physiological variable indicated by +, -, or 0, with actual value for amount of change given where data are available. Control value of reference series is not always the same as the control value in table. Abbreviations: R = reclining; S = sitting; St = standing; Sp = supine; B = basal; 1/2 H-R = 1/2 hour rest; B-R = bed rest; S-R = short rest; U = uncontrolled; P-I = premature infant; F-I = full-term infant; N-C = normal children; A-P = to age of puberty; Sl = sleeping; S-D = standard deviation; B-M = before menstruation; F-M = after menstruation; A-C = antecubital; I-J = internal jugular; E-J = external jugular; F = femoral; D-H = dorsal hand; A = arterial; C = cutaneous; V = venous.

	Control or Factor Varied	Conditions of Observation						Subjects no.	Hb mM/L	Adjusted pH	Whole Blood CO_2 mM/L	Adjusted pCO_2 mm Hg	Calc. $(BB)_b$ mEq/L	Alveolar Air		Reference
		Posture	Age	Sex	Time	Activity	Other							Subjects no.	pCO_2 mm Hg	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
	Cutaneous Blood (concluded)															
17	Day to day variability	S	16-28 yr	♂	8-9 AM	1/2 H-R	S-D[9]	8	±	±0.04[10]	±1.0[10]	±4.7[10]	±			B-M,9
18		S	16-28 yr	♀	8-9 AM	1/2 H-R	S-D[9]	7	±	±0.07[10]	±1.7[10]	±4.8[10]	±			B-M,9
19		Sp	27 yr	♀	8 AM	S-R	8-10 da B-M			+0.03	?[11]	-4.7	-	1[8]	-4.7	B-H,J-O, 12
20		Sp	27 yr	♀	8 AM	S-R	1-13 da F-M			+0.01	?[11]	-2.7	-	1[8]	-2.7	B-H,J-O, 12
	Venous Blood															
21	Control	Sp	16-50 yr[11]	♂	Day	1/2 H-R	A-C	60	68%[12]	7.36	23.9	50	49			B-M,13
22	Vein used	Sp	18-50 yr	♂	Day	1/2 H-R	I-J	60	-5%[12]	-	+0.8	+				B-L,13
23		Sp	16-50 yr	♂	Day	1/2 H-R	E-J	40	+19%[12]	+	-0.7	-	0			B-M,13
24		Sp	16-50 yr	♂	Day	1/2 H-R	F	14	+2%[12]	0	+0.1	+	0			B-M,13
25		R	20-50 yr[11]	♂	Day	1/2 H-R	D-H	33	+18%[12]	+	-1.4	-	0			B-M,14
26	Temperature	R	20-50 yr[11]	♂	Day	1/2 H-R	A-C, 28°C	15	+5%[12]	+	-0.3	-	0			B-M,14
27		R	20-50 yr[11]	♂	Day	1/2 H-R	A-C, 23°C	15	-4%[12]	-	+0.2	+	0			B-M,14
28		R	Adult	♂	Day	1/2 H-R	D-H, 45°C	4	+30%[12]	+0.03	-2.2	-8	0			B-M,15

/8/ Posture of subjects, supine; activity, basal. /9/ Values in Lines 17 and 18, Columns I-M, are group means of the standard deviation values for all subjects. /10/ Standard deviation of the distribution of the group of standard deviations about the standard deviation: Lines 17 and 18, Column J = ±0.02; Lines 17 and 18, Column K = ±0.2; Line 17, Column L = ±0.7; Line 18, Column L = ±1.0. /11/ Possibly negative change. /12/ Oxygen saturation.

Contributors: (a) Singer, R. B., and Hastings, A. B.

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79. ACID-BASE BALANCE OF BLOOD: VERTEBRATES

pH adjusted to body temperature by applying correction of -0.015 per °C temperature difference (cf Table 78, Part I, Line 10). CO_2 pressure calculated by means of Henderson-Hasselbalch equation; value of pK'_1 increases 0.005 per °C decrease in temperature, and f_{CO_2} is assumed to increase proportionately as it does in pure water. The following values of pK'_1 and f_{CO_2} were used at temperatures other than 38°C: 5°, 6.26 and 0.0864; 10°, 6.24 and 0.0697; 20°, 6.19 and 0.0508; 26°, 6.16 and 0.0434; 34°, 6.12 and 0.0357; 40°, 6.09 and 0.0313; 42°, 6.08 and 0.0303. Abbreviations: A = arterial; H = heart; M = mixed arterial and venous; V = venous. Values in parentheses are ranges, estimate "b" or "c" of the 95% range (cf Introduction).

	Animal	Body Temp °C	Blood	Whole Blood: pH	Whole Blood: Hemoglobin mM/L	Whole Blood: RBC Vol %	Plasma: CO_2 Content mM/L	Plasma: CO_2 Pressure mm Hg	Plasma: Na^+ mEq/L	Plasma: Cl^- mEq/L	Plasma: H_2O g/L	Plasma: Protein g/L	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
	Mammals[1]												
1	Man, adult male	37	A	7.39(7.33-7.45)[b]	9.0	45	27.0(25-29)[b]	42(36-47)[b]	138(132-144)[b]	102(97-108)[b]	940	68	B-D,G-J,1;E,K,L,2
2	Cat	38.6	M	7.35(7.24-7.40)[c]			20.4(17-24)[b]	36	153(150-156)[b]	120(117-123)[b]	941		B,3;C-K,4
3	Anesthetized	38.6	V	7.28(7.18-7.35)[c]	6.8	40	21.8(19-25)[c]	45(34-52)[c]		108(105-111)[c]	942	76	B,3;C,D,G-K,5;E,F,6;L,7
4	Cow	38.5	A	(7.35-7.50)[2]	7.0	40					930	83	B,C,3;D,8;E,F,9;K,a;L,7
5	Dog	38.9	A	7.36(7.31-7.42)[c]	9.0	46	21.4(17-24)[c]	38	147(140-154)[b]	114(108-119)[b]	941	67	B,10;C,D,G,H,10-12;E,F,6; 1-K,13;L,7
6	Dolphin		H	7.38		44	30.9		153(149-155)[c]	110(105-115)[c]		78	C-L,14
7	Guinea pig	38.6	H, A	7.35(7.17-7.55)[c]	8.7	42	22.0(16-26)[c3]	40(19-59)[c]	141(138-144)[c]	104(100-108)[c]	954	47	B-D,G,H,16;E,F,6;I,J,15;K,a; L,7
	Hamster												
8	Anesthetized	38	H, V	7.39(7.37-7.44)[c]	8.4	46	37.3(35-39)[c]	59(54-61)[c]	144(140-151)[c]	106(103-108)[c]	945		B-D,G,H,17;E,F,9;I,J,15;K,a
9	Hibernating	5	H, V	7.44(7.34-7.56)[c]			42.4(35-50)[c]	32(26-42)[c]					B-H,17
10	Horse	37.8	V	(7.20-7.55)[c]	6.8	33	28.1(24-32)[c]	47	135	96	931	68	B-D,3;E,F,9;G,18;H,a;1-K,19; L,7
11	Rabbit	39.4	A	7.35(7.21-7.57)[c]	7.2		22.8(13-33)[c3]	40(22-51)[c]	140(139-142)[c]	102(99-105)[c]	944		B,C,3,16;D,G,H,16,20;E,F,1,J, 20;K,a
12		39.6	H, A	7.32(7.30-7.36)[c]		42	18.0(11-26)[c3]	33(20-48)[c]	138(122-144)[c]	104(84-110)[c]		62	B-M,21
13	Rat[4]	38.2	A	7.35(7.26-7.44)[b]	9.0	46	24.0(20-28)[b]	42	144(135-155)[b]	104(99-112)[b]	946	60	B,16;C,D,G-J,22,23;E,F,6;K, 22;L,7
14		38.0	A	7.38(7.31-7.45)[b]			20.8(14-28)[b]	34	135(130-140)[b]	102(97-107)[b]			B-J,24
15	Sheep	39.1	V	7.44(7.32-7.54)[c]	7.6	32	26.2(21-28)[c]	38	153(146-161)[c]	103(98-109)[c]	947	57	B,3;C,D,G-J,25;E,F,9;K,a;L,7
16	Squirrel, ground	38	H	7.43(7.38-7.52)[c]		53	20.5(18-23)[c5]						B-G,26
17	Hibernating	10	H	7.10(7.01-7.20)[c]		58	38.6(33-40)[c5]						B-G,26
	Birds[5]												
18	Chicken	41.7	V	7.54(7.45-7.63)[c]	6.8	32	23.0(21-26)[c]	26	154(148-161)[c]	117(109-120)[c]	960	36	B,C,3;D,27;E,F,9;G,28;H,K,a; I,J,15;L,7
	Reptiles[6]												
19	Alligator[7]	5	H, M	7.74	4.2	25	36.1	15		110	958	41	B-J,L,29;K,a
20		26	H, M	7.30(6.87-7.66)[c]	4.3	22	23.5(15-40)[c]	38	154(146-162)[c]	107(83-128)[c]	952	50	B-J,L,30;K,a
21		34	H, M	7.43	5.4		19.8	29		105	954	46	B-J,L,29;K,a
22	Chameleon	26	H, M	7.26(6.93-7.63)[c]	4.2	28	15.4(10-22)[c]	27	157(139-186)[c]	127(113-133)[c]	958	41	B-J,L,31;K,a
23	Iguana, black	26	H, M	7.22(7.05-7.42)[c]	3.6	35	14.5(10-22)[c]	28	159(158-163)[c]	133(128-137)[c]	940	68	B-J,L,32;K,a
24	Iguana, common	26	H, M	7.48(7.38-7.57)[c]	4.2	30	24.4(15-33)[c]	27	157(142-165)[c]	118(110-124)[c]	952	50	B-J,L,32;K,a

/1/ Homoiothermic, body temperature relatively independent of environmental temperature except in hibernating animals. /2/ Venous blood. /3/ Calculated from whole blood CO_2 content, pH and hemoglobin by means of nomogram of Singer and Hastings [41]. /4/ The rat sometimes varies significantly in acid-base balance from one laboratory series to another. /5/ Values for whole blood. /6/ Poikilothermic, body temperature closely dependent on environmental temperature. When temperature is decreased, pH and CO_2 solubility coefficient increase, and oxygen dissociation curve is shifted to left. /7/ The alligator shows a marked variation, between individuals and within the same individual at different seasons, and a prolonged and extreme "alkaline tide" following meals [42].

79. ACID-BASE BALANCE OF BLOOD: VERTEBRATES (Concluded)

pH adjusted to body temperature by applying correction of -0.015 per °C temperature difference (cf Table 78, Part 1, Line 10). CO_2 pressure calculated by means of Henderson-Hasselbalch equation; value of pK'_1 increases 0.005 per °C decrease in temperature, and f_{CO_2} is assumed to increase proportionately as it does in pure water. The following values of pK'_1 and f_{CO_2} were used at temperatures other than 38°C: 5°, 6.26 and 0.0864; 10°, 6.24 and 0.0697; 20°, 6.19 and 0.0508; 26°, 6.16 and 0.0434; 34°, 6.12 and 0.0357; 40°, 6.09 and 0.0313; 42°, 6.08 and 0.0303. Abbreviations: A = arterial; H = heart; M = mixed arterial and venous; V = venous. Values in parentheses are ranges, estimate "b" or "c" of the 95% range (cf Introduction).

	Animal	Body Temp °C	Blood	Whole Blood: pH	Whole Blood: Hemoglobin mM/L	Whole Blood: RBC Vol %	Whole Blood: CO_2 Content mM/L	Whole Blood: CO_2 Pressure mm Hg	Plasma: Na^+ mEq/L	Plasma: Cl^- mEq/L	Plasma: H_2O g/L	Plasma: Protein g/L	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
	Reptiles[6] (concluded)												
25	Snake	26	H	7.25(7.12-7.50)c		28	6.6(3-16)c		156(143-169)c	130(122-143)c		42	B-L,33
26	Turtle	26	H	7.65(7.50-8.10)c		25	24.4(18-32)c		125(114-135)c	92(80-100)c			B-J,34
	Fish[6]												
27	Carp	20	H, V	7.39(7.33-7.45)c	6.4	31	17.7(14-22)c	22	130(126-137)c	107(96-121)c	957	42	B,C,H,K,a;D,G,35;E,F,1,L,36; J,37
28		15	V			39	13.5[5]	8.5[5]		147	951		B-K,38
29	Skate	10.4	A	7.82	2.7	20	3.5	1.3	254(219-289)c	255(230-285)c	967	27	B-H,L,39;1,J,40;K,a
30	Trout	15	V			35	9.5[5]	9.0[5]		140	955		B-K,38

/5/ Values for whole blood. /6/ Poikilothermic, body temperature closely dependent on environmental temperature. When temperature is decreased, pH and CO_2 solubility coefficient increase, and oxygen dissociation curve is shifted to left.

Contributors: (a) Singer, R. B., (b) Irvin, J. L., (c) Hernandez, T.

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80. ACID-BASE IMBALANCE OF BLOOD: MAN

Part I: DEFINITIONS

For a thorough consideration of the physicochemical laws, the physiological regulations, and the pathological states pertaining to acid-base disturbances in man, refer to the classic work of Henderson [1], Peters and Van Slyke [2], and to material of more recent date [3-6]. Definitions apply to Tables 78-80.

	Term (A)	Definition (B)
1	Acid	A chemical compound capable of dissociating in solution to form H^+ ions and negatively charged ions (anions), e.g., HCl (strong acid), H_2CO_3 (weak acid).
2	Base	A chemical compound capable of neutralizing an acid or dissociating in solution to form OH^- ions and positively charged ions (cations), e.g., NaOH (strong base), NH_4OH (weak base), $NaHCO_3$ (buffer salt, neutralizes strong acids). This definition avoids the undesirable past usage, in acid-base literature, of "base" as synonynous with "cation", and also the more modern but confusing Bronsted definition of base as an H^+ acceptor (e.g., the anion HCO_3^- would be called a "base") [7].
3	Buffer base	Biological buffer salts capable of neutralizing strong acids; in blood--the appropriate fraction of total cation and equivalent buffer anions, chiefly bicarbonate, hemoglobinate, and proteinate.
4	Acidosis	An abnormal condition caused by the accumulation in the body of an excess of acid, or the loss from the body of base [2].
5	Alkalosis	An abnormal condition caused by the accumulation in the body of an excess of base, or the loss from the body of acid [2].
6	Respiratory factor	If the acid concerned in the disturbance is H_2CO_3, the acidosis or alkalosis may be called "respiratory." The best index for this factor is the CO_2 pressure, pCO_2 of arterial or cutaneous blood, which is normally equal to the pCO_2 of alveolar air. It can be calculated from plasma pH and total CO_2 by the Henderson-Hasselbalch equation (Page 86, Table 78, Line 5), or measured directly. Venous pCO_2 is less desirable because of variability of arterio-venous difference of 2-10 mm or more (Pages 88-89, Table 78, Parts II and III).
7	Metabolic factor	If a base or some acid other than H_2CO_3 is concerned in the disturbance, the acidosis or alkalosis may be called "metabolic." A satisfactory quantitative index for this factor is the whole blood buffer base concentration [5], or the plasma bicarbonate concentration at pH 7.4 [2]. The total CO_2 or bicarbonate concentration is not satisfactory because it also varies with pCO_2, the respiratory factor [1, 2, 5]. The plasma CO_2 combining power, still widely used, is even less satisfactory because it does not measure directly any variable in blood or plasma [2, 5, 8]. Buffer base can be calculated from pH, total CO_2, hemoglobin, and plasma protein (Page 86, Table 78, Line 7), or taken from a nomogram [5].
8	Compensation	In blood, pCO_2 and buffer base can be regarded as independent variables sufficient to define the state of acid-base balance. The pH and total CO_2 or bicarbonate, usually the variables determined, are better regarded as dependent variables. A primary disturbance in one factor, pCO_2 or buffer base, usually results in compensation, one manifestation of which is a change in the other factor in such a way that the pH is returned toward, but not necessarily to, the normal range (Page 98, Part IV).

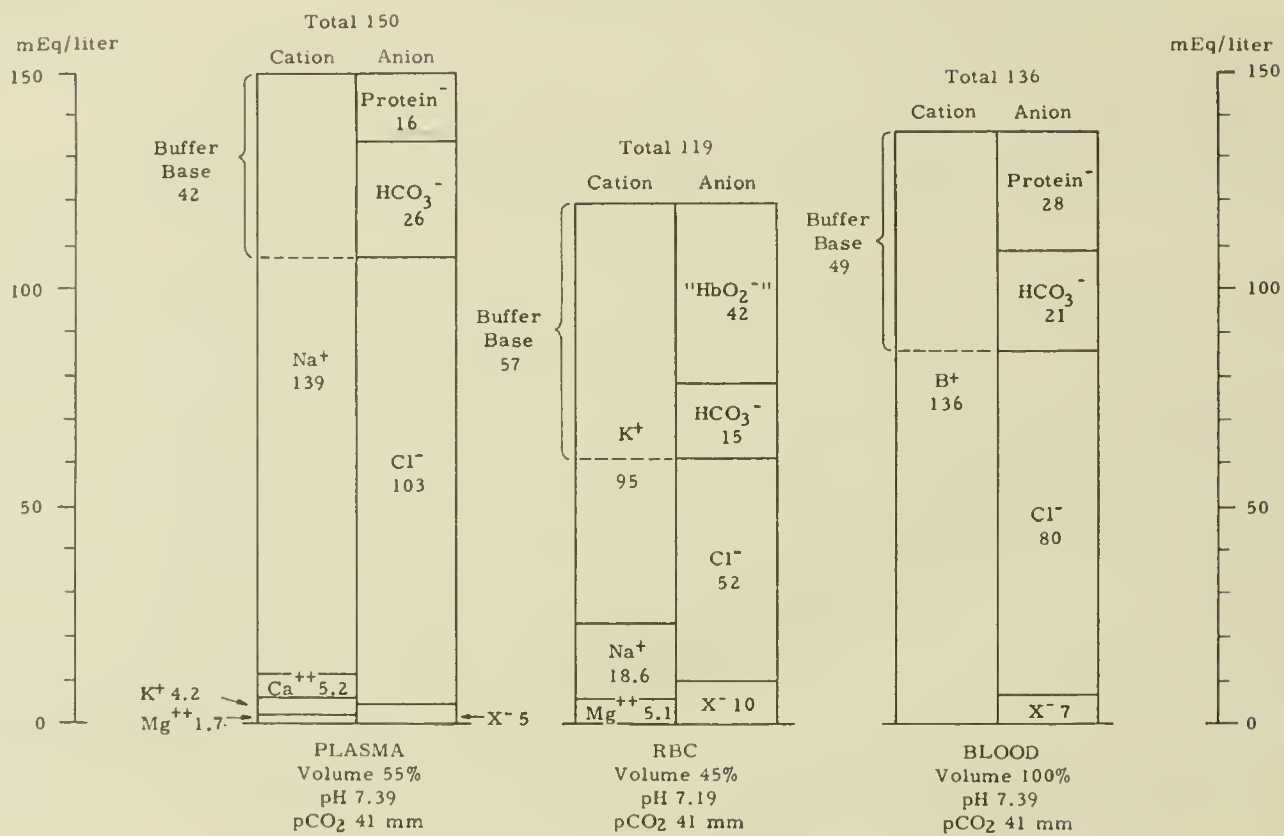
Contributor: Singer, R. B.

References: [1] Henderson, L. J., "Blood, A Study in General Physiology," New Haven: Yale Univ. Press, 1928. [2] Peters, J. P., and Van Slyke, D. D., "Quantitative Clinical Chemistry," vol I, 1st ed., Baltimore: Williams and Wilkins Co., 1931. [3] Shock, N. W., and Hastings, A. B., J. Biol. Chem. 112:239, 1935. [4] Shohl, A. T., "Mineral Metabolism," New York: Reinhold Publishing Co., 1939. [5] Singer, R. B., and Hastings, A. B., Medicine, Balt. 27:223, 1948. [6] Elkinton, J. R., and Danowski, T. S., "The Body Fluids," Baltimore: Williams and Wilkins Co., 1955. [7] Clark, W. M., "Topics in Physical Chemistry," Baltimore: Williams and Wilkins Co., 1948. [8] Davenport, H. W., "The ABC of Acid-Base Chemistry," Chicago: Univ. of Chicago Press, 1950.

80. ACID-BASE IMBALANCE OF BLOOD: MAN (Continued)

Part II: NORMAL IONIC PATTERNS, ARTERIAL BLOOD

Diagram is included at this point for use in conjunction with classification of acid-base disturbances (Part III on facing page). Values shown are for adult male, based on the literature. X^- = undetermined anion residue. "HbO_2" includes such other RBC buffer anions as organic phosphate. Whole blood pH = plasma pH. pCO_2 = CO_2 partial pressure or tension. B^+ = mEq total cation (Na^+, K^+, etc.) in one liter blood, on basis of hematocrit value of 45% RBC. Buffer base = the appropriate fraction of total cation and its equivalent amount, the labile fraction of total anions, i.e., proteinate, bicarbonate, oxyhemoglobinate, organic phosphate, and other RBC buffer anions.



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Part III: CLASSIFICATION

Ranges for acid-base variables, as reported in the literature or inferred from related observations, for adult arterial or cutaneous blood. See also normal values (Pages 88 and 90, Table 78, Parts II and IV) and Acid-Base Pathways (Page 98, Part IV). Limits given are approximate; designation underlined is the best index for existence of the given condition.

	Condition	Buffer Base[1] mEq/L	CO_2 Pressure mm Hg	Bicarbonate[2] mEq/L	pH at 37°C
	(A)	(B)	(C)	(D)	(E)
1	Normal, arterial or cutaneous blood	46-52	35-45	24-28	7.35-7.45
2	Metabolic acidosis (acid excess or base deficit)	<u>Always low</u> <u>20-46</u>	Usually low 15-35	Usually low 4-24	Usually low 6.8-7.35
3	Respiratory acidosis (H_2CO_3 excess)	Normal or high 46-70	<u>Always high</u> <u>45-100+</u>	Usually high 28-45	Usually low 7.0-7.35
4	Metabolic alkalosis (base excess or acid deficit)	<u>Always high</u> <u>52-75</u>	Normal or high 35-55	Usually high 28-50	Usually high 7.45-7.65
5	Respiratory alkalosis (H_2CO_3 deficit)	Normal or low 40-52	<u>Always low</u> <u>10-35</u>	Usually low 15-24	Usually high 7.45-7.70
6	Mixed acidosis (combination Lines 2 and 3)	Always low 25-45	Always high 45-100	Variable 10-35	Always low 6.8-7.35
7	Mixed alkalosis (combination Lines 4 and 5)	Always high 52-70	Always low 15-35	Variable 20-45	Always high 7.5-7.7
8	Mixed "hypercapnia" (combination Lines 3 and 4)	Always high 52-75	Always high 45-100	Always high 30-50	Variable 7.3-7.6
9	Mixed "hypocapnia" (combination Lines 2 and 5)	Always low 20-46	Always low 10-35	Always low 4-22	Variable 7.0-7.6

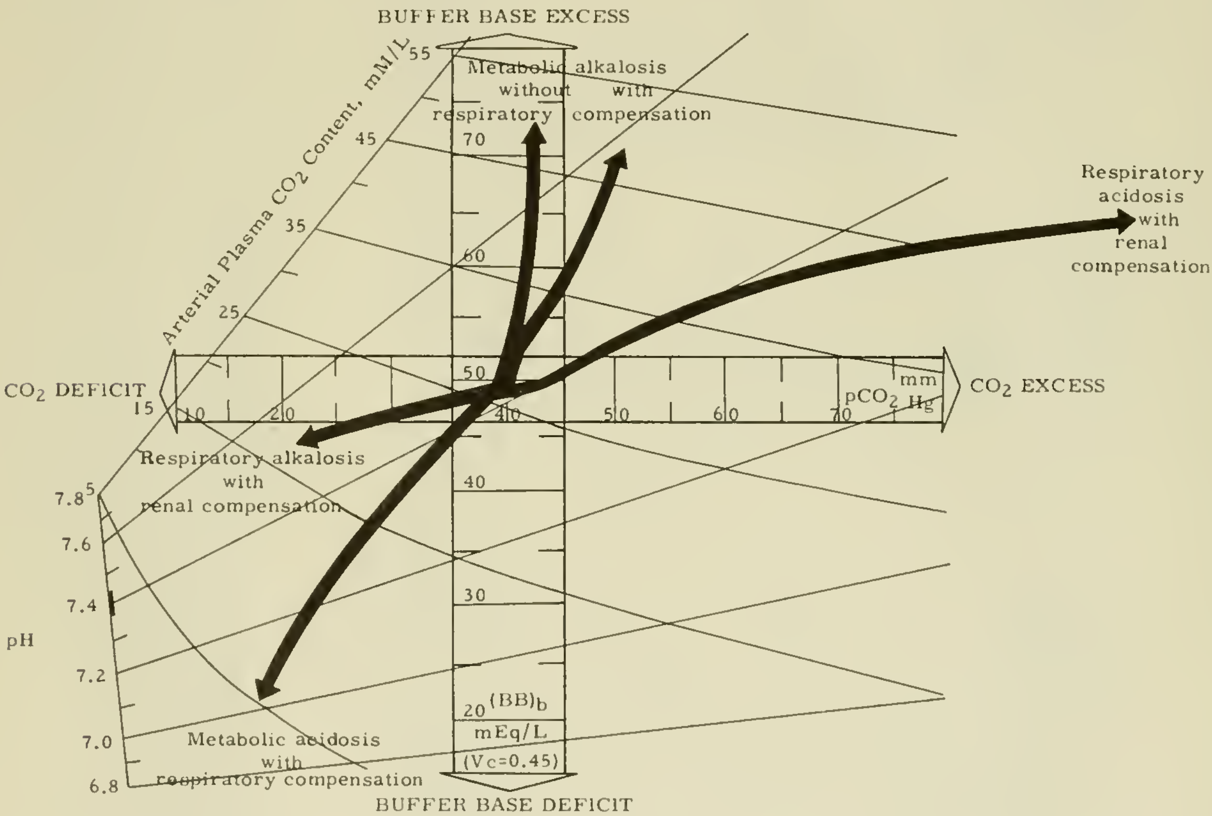
/1/ Buffer base for whole blood of normal hemoglobin concentration = 15 g/100 ml. A decrease in buffer base of whole blood is almost always accompanied by a decrease in plasma or extracellular Na^+ relative to $Cl^- + X^-$, e.g., decrease in $(Na^+)p$, increase in $(Cl^-)p$ or $(X^-)p$, or any appropriate combination. An increase in buffer base of whole blood is accompanied by an increase in Na^+ relative to $Cl^- + X^-$, e.g., increase in $(Na^+)p$, decrease in $(Cl^-)p$, or any appropriate combination. See normal values in diagram on facing page. /2/ Comprises about 90-98% of total CO_2 in plasma, average 95%.

Contributor: Singer, R. B.

References: [1] Peters, J. P., and Van Slyke, D. D., "Quantitative Clinical Chemistry," vol 1, 1st ed., Baltimore: Williams and Wilkins Co., 1931. [2] Singer, R. B., and Hastings, A. B., Medicine, Balt. 27:223, 1948.

Part IV: PATHWAYS

Any point on this acid-base diagram [1] gives simultaneously occurring values of four variables: (1) whole blood buffer base $(BB)_b$, the metabolic factor in the disturbance; (2) CO_2 pressure (pCO_2), the respiratory factor; (3) plasma CO_2 content; and (4) pH. The scale of $(BB)_b$ is strictly accurate only for oxygenated human blood at 37°C having a hematocrit value of 45% or hemoglobin concentration of 15 g/100 ml. The width of the buffer base bar corresponds to the "normal" range of arterial pCO_2 selected, namely, 35-45 mm Hg. Similarly, the width of the pCO_2 bar is the normal range for $(BB)_b$, from 46-52 mEq/L. The heavy arrows represent typical average pathways of the four principal types of acid-base disturbance (Part II). They are based on observations of the contributor and colleagues [1-4], but are representative of similar clinical data in the literature. In metabolic acidosis, respiratory compensation is almost always present [2]; in metabolic alkalosis, respiratory compensation is frequently absent, especially under clinical conditions [3, 4]. In acute, experimental, respiratory disturbances the pathways are in the horizontal pCO_2 bar, with virtually no change in $(BB)_b$ [5]. The four mixed types of acid-base disturbance are not shown on the diagram, but the possible areas may be located from the classification in Part III. Examples of these disturbances are mixed acidosis in thoracic surgery under ether anesthesia [6], mixed alkalosis in many dyspneic patients with congestive heart failure [7], mixed hypercapnia in some cases of cor pulmonale [4], and mixed hypocapnia in severe salicylate intoxication [2].



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References: [1] Singer, R. B., Am. J. M. Sc. 221:199, 1951. [2] Singer, R. B., Medicine, Balt. 33:1, 1954. [3] Singer, R. B., Deering, R. C., and Clark, J. K., J. Clin. Invest. 35:245, 1956. [4] Singer, R. B., unpublished. [5] Shock, N. W., and Hastings, A. B., 112:239, 1935. [6] Beecher, H. K., and Murphy, A. J., J. Thorac. Surg. 19:50, 1950. [7] Squires, R. D., Singer, R. B., Moffitt, G. R., Jr., and Elkinton, J. R., Circulation, N. Y. 4:697, 1951.

Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Variable (A)		Sex (B)	Value (C)	Reference (D)
1	RBC count, millions/cu mm blood		♂	5.4(4.6-6.2)	1, 2
2			♀	4.8(4.2-5.4)	1, 2
3			♂♀	5.1	1, 2
4	RBC packed volume[1] (hematocrit),		♂	47(40-54)[2]	2, 3
5	ml/100 ml blood		♀	42(37-47)[2]	2, 3
6			♂♀	44.5	2, 3
7	Blood hemoglobin concentration,		♂	16.3(14.5-18.1)	4
8	g/100 ml blood		♀	14.5(12.3-16.7)	4
9			♂♀	15.4	4
10	RBC hemoglobin concentration, g/100 ml RBC		♂♀	33.5(30-40)[2]	1, 2
11	RBC hemoglobin content, μμg		♂	29(25-34)	2
12			♀	29(24-33)	2
13			♂♀	29(23-35)	2
14	RBC, cu μ		♂	87(70-94)[2]	2
15			♀	87(74-98)[2]	2
16			♂♀	87	2
17	RBC circulating volume, ml/kg		♂	28.3(20.3-36.3)	5
18	body wt		♀	24.2(19.0-29.4)	5
19			♂♀	26.3	5
20	RBC specific gravity[3]		♂	1.093(1.089-1.097)	6, 7
21	RBC mass, μμg[4]		♂	95(76-103)	6, j
22	RBC iron content,[5] μμg		♂♀	0.10(0.08-0.12)	2, 8, 9
23	RBC life span, da[6]		♂♀	120(108-130)	10
24	RBC and Hb replaced, % of total/da		♂♀	0.83	1, 2, 11
25	RBC (intracellular) pH		♂	7.24(7.21-7.26)	12
26	RBC spherocytic index		♂♀	0.27	1, 2
27	RBC charge, millivolts[7]		♂♀	-16.8	13
28	RBC electrophoretic mobility, sq cm/volt sec[7]		♂♀	1.31×10^{-4}	13
29	RBC diameter, μ	Dry	♂♀	7.5(7.2-7.8)[8]	1, 14
30		Plasma	♂♀	8.4(7.4-9.4)	15
31	RBC thickness, μ	Dry	♂♀	2.0(1.7-2.2)[9]	1, 2
32		Plasma	♂♀	2.4	15
33	RBC surface area,	Dry	♂♀	135(129-146)[10]	2, h
34	sq μ	Plasma	♂♀	163	15
35	RBC sedimentation rate,	Westergren method	♂	(0-15)	16
36	mm/hr		♀	(0-20)	16
37		Wintrobe method	♂	(0-9)	17
38			♀	(0-15)	17
39		Cutler method	♂	(0-8)	18
40			♀	(0-10)	18
	RBC fragility, % NaCl solution	Doland and Worthley method			
41		Initial	♂♀	0.47(0.48-0.46)	19
42		Final	♂♀	0.27(0.30-0.24)	19
		Giffin and Sanford method			
43		Initial	♂♀	(0.44-0.42)	20
44		Final	♂♀	(0.34-0.32)	20
		Parpart method			
45		Mean	♂	0.43(0.54-0.32)	21

/1/ Centrifuged at 2000 G or over (= 3000 rpm) for 10 min after attaining constant packed cell volume [2]. /2/ Heparin or other isotonic anticoagulant. When anticoagulant = 2 mg K oxalate/ml blood, mean and 95% range for Column C, Line 4 = 45(40-50); Line 5 = 41(36-45); Line 10, ♂ = 35(30-40), ♀ = 34(30-40); Line 14 = 82(70-94); Line 15 = 86(74-97). [2] /3/ Specific gravity of RBC at 25°C referred to water at 4°C [6]. /4/ Calculated from volume (16C) and specific gravity (20C). [6, j] /5/ Calculated from Hb content (13C), using 0.339 as % Fe in Hb [2, 8, 9]. /6/ Use of radioactive chromium 51; other methods in essential agreement. [10] /7/ M/15 phosphate buffer at pH 7.4 [13]. /8/ Diffraction, or by 500 or more measurements with micrometer eyepiece. Range = range of means. [1, 14] /9/ Calculated from RBC volume (16C) and dry diameter (29C) by formula $t = V/\pi r^2$ [1, 2]. /10/ Calculated from RBC volume (16C) and dry thickness (31C) by formula $A = 2\pi r\,(r+t)$ [2, h].

Contributors: (a) Bethell, F. H., (b) Carlsen, E., (c) Collier, H. B., (d) Dole, V. P., (e) Ebaugh, F. G., Jr., (f) Ferguson, J. H., (g) Gram, H. C., (h) Guest, G. M., (i) Hirschboeck, J. S., (j) Osgood, E. E., (k) Ponder, E., (l) Riser, W. H., Jr., (m) Van Slyke, D. D.

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82. ERYTHROCYTE AND HEMOGLOBIN VALUES IN PREGNANCY AND POSTPARTUM: MAN

Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Period	RBC Count millions/cu mm blood	RBC Packed Volume (Hematocrit) ml/100 ml blood	Blood Hb Concentration g/100 ml blood	RBC Hb Concentration g/100 ml RBC	RBC Hb Content μμg	RBC Volume cu μ
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Second trimester						
1	4th mo	4.5(3.8-5.2)	40(35-45)	12.8(11.4-15.0)	32	28.4	89
2	5th mo	4.3(3.7-5.0)	39(34-44)	12.2(10.8-14.6)	31	28.4	91
3	6th mo	4.0(3.5-4.8)	37(32-42)	11.4(10.2-14.0)	31	28.5	92
	Third trimester						
4	7th mo	4.0(3.5-4.8)	37(32-42)	11.4(10.2-14.0)	31	28.5	92
5	8th mo	4.1(3.5-4.8)	37.5(33-43)	11.6(10.4-14.2)	31	28.3	91
6	9th mo	4.2(3.7-5.0)	37.5(33-43)	12.0(10.8-14.4)	32	28.5	89
7	During labor	4.4(4.0-5.0)	39(34-44)	12.6(11.2-15.0)	32	28.6	89
	Postpartum						
8	10 da	4.5(4.0-5.0)	40(35-45)	12.8(11.4-15.4)	32	28.4	89
9	42 da	4.8(4.2-5.4)	42.5(37-47)	13.8(12.0-16.0)	32.5	28.7	89

Contributor: Bethell, F. H.

Reference: Bethell, F. H., Gardiner, S. H., and Mackinnon, F., Ann. Int. M. 13:91, 1939.

83. ERYTHROCYTE AND HEMOGLOBIN VALUES IN FETUS, NEWBORN, AND ADULT FEMALE: MAMMALS

Values given for adult female are not necessarily those of the mother. Values in parentheses are ranges and conform, unless otherwise specified, to estimate "c" of the 95% range (cf Introduction).

	Stage of Development	RBC Count millions/cu mm blood	RBC Packed Volume (Hematocrit) ml/100 ml blood	Blood Hb Concentration g/100 ml blood	RBC Hb Content μμg	RBC Volume cu μ	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Man						
	Fetus at fraction of term/1/						
1	0.3	1.1(0.3-2.2)	27(23-33)	9.3(8.0-10.9)	63(47-97)	191(134-285)	B-F,1
2	0.4	2.8(2.3-3.5)	33(29-44)	10.7(6.0-13.1)	40(35-48)	131(113-150)	B-F,1
3	0.5	2.8(2.2-3.5)	36(30-41)	11.5(8.7-14.6)	42(38-51)	129(116-140)	B-F,1
4	0.6	3.5(2.9-4.1)	44(36-52)	13.6(11.0-14.7)	39(33-45)	125(116-136)	B-F,1
5	Newborn	4.8(3.8-6.0)/2/	51.3(41-61)/2/	17.9(13.0-22.0)/2/	37.5(32-43)	113(90-124)	B,D-F,2;C,3
6	Adult female	4.8(4.2-5.4)b	42(37-47)b	14.5(12.3-16.7)b	29(24-33)b	87(74-98)b	B,C,E,F,4;D,5
	Cat						
	Fetus at fraction of term/3/						
7	0.6	2.22	28.0	7.9	36	134	B-F,6,7
8	0.7	3.12(2.61-3.78)	30.5(26-36)	9.1(7.5-10.7)	28(24-38)	99(94-103)	B-F,6,7

/1/ Gestation period = 280 da. /2/ Cord or venous blood; capillary blood values may increase as much as 20% during first week after birth. [14] /3/ Gestation period = 60 da.

Values given for adult female are not necessarily those of the mother. Values in parentheses are ranges and conform, unless otherwise specified, to estimate "c" of the 95% range (cf Introduction).

	Stage of Development	RBC Count millions/cu mm blood	RBC Packed Volume (Hematocrit) ml/100 ml blood	Blood Hb Concentration g/100 ml blood	RBC Hb Content µµg	RBC Volume cu µ	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Cat (concluded)						
9	0.8	3.80(3.24-4.25)	34.3(30-41)	10.1(9.3-11.2)	27(23-30)	91(81-97)	B-F,6,7
10	Newborn, 3-12 da	5.70(5.16-6.14)	39.3(35-48)	12.4(9.6-15.1)	22(19-26)	68(65-78)	B-F,6,7
11	Adult female	6.6	34.2	11.8	18	51	B-F,6,7
	Cow						
	Fetus at fraction of term[1]						
12	0.3	3.9(3.7-4.1)	37.7(34-40)	8.5(7.7-9.1)	21.3(20.5-22.0)	93(91-97)	B-F,8
13	0.4	4.8(4.5-5.3)	43.0(40-47)	10.9(10.3-11.4)	21.1(20.0-21.6)	88(84-89)	B-F,8
14	0.5	4.8(3.8-5.5)	36.7(28-45)	8.5(6.9-9.7)	18.6(17.5-20.2)	77(74-83)	B-F,8
15	0.6	5.5(4.4-6.4)	40.4(32-50)	9.6(7.7-11.2)	17.5(17.4-17.6)	74(71-77)	B-F,8
16	0.7	5.2(4.2-6.2)	37.0(32-44)	9.7(8.3-12.1)	18.6(16.5-19.6)	71(69-75)	B-F,8
17	0.8	5.9(5.4-8.0)	39.7(35-47)	9.8(8.8-11.5)	15.0(14.3-16.2)	57(58-63)	B-F,8
18	0.9	6.1(5.9-6.2)	31.0(30-32)	8.4(8.3-8.5)	13.9(13.4-14.3)	51(49-53)	B-F,8
19	Fetus at term[4]	6.8(6.0-7.8)	35.9(32-42)	9.6(8.5-10.8)	14.1(13.7-14.5)	53(50-54)	B-F,8
20	Adult female	8.05(6.1-10.7)	38.6(31-54)	12.9(9.2-18.3)	15.7(14.2-18.5)	50(47-54)	B-F,8
	Goat						
	Fetus at fraction of term[5]						
21	0.3		19	4.2			C,D,9
22	0.5		31(29-33)	7.1(5.2-9.1)			C,D,9
23	0.6		40	10.1			C,D,9
24	0.7		22	9.0			C,D,9
25	0.8		32	10.4			C,D,9
26	0.9		28.5(28-29)	8.9(8.2-9.6)			C,D,9
27	Fetus at term[6]		27	9.4			C,D,9
28	Newborn, 24-48 hr		33(29-36)	11.0(9.9-12.4)			C,D,9
29	Adult female		50	12.6			C,D,9
	Pig						
	Fetus at fraction of term[7]						
30	0.2	0.25(0.1-0.5)	6.6(3.6-10.6)			244(204-361)	B,C,F,6,7
31	0.3	0.63(0.2-1.3)	10.3(4.2-20.0)	3.3(1.5-4.9)	56(38-87)	173(131-278)	B-F,6,7
32	0.4	2.5(0.68-3.9)	26.2(10.2-33.0)	6.9(2.6-10.6)	27(19-40)	100(80-149)	B-F,6,7
33	0.5	2.9(2.0-4.0)	27.4(23-35)	6.8(4.9-11.2)	23(17-29)	94(84-114)	B-F,6,7
34	0.6	3.0(2.1-4.0)	30.3(19.1-38.0)	8.1(5.2-9.7)	27(21-35)	101(85-112)	B-F,6,7
35	0.7	4.0(3.0-4.4)	31.0(29-34)	7.0(6.5-9.6)	25(19-31)	101(95-107)	B-F,6,7
36	0.8	3.9(3.0-4.4)	32.4(29-36)	8.7(7.6-9.6)	22(20-28)	80(77-96)	B-F,6,7
37	0.9	4.16(4.0-4.3)	34.5(33-36)	9.3(8.8-9.7)	22.5(22-23)	83(83-83)	B-F,6,7
	Newborn						B-F,6,7
38	1-12 hr	5.72(5.51-5.91)	39.6(39-40)	11.8(11.8-12.0)	21(20-22)	69(68-71)	B-F,6,7
39	1-10 da	3.9(2.62-5.26)	25.0(18-36)	8.1(5.4-10.1)	20(16-22)	64(59-69)	B-F,6,7
40	Adult female	6.93	40.8	13.8	21	59	B-F,6,7
	Rabbit						
	Fetus at fraction of term[8]						
41	0.6	1.9(1.6-2.0)	22.3(21-23)	7.3(7.1-7.7)	44(35-46)	120(113-133)	B-F,6,7
42	0.7	2.9(2.1-3.4)	34.4(23-38)	9.6(7.7-11.1)	35(27-48)	122(108-154)	B-F,6,7
43	0.8	2.8(2.3-3.1)	32.0(28-37)	8.8(10.1-11.0)	36(31-47)	113(99-123)	B-F,6,7
44	0.9	3.7(2.9-4.3)	30.5(24-34)	10.0(8.5-11.3)	28(26-30)	82(79-84)	B-F,6,7
	Newborn						
45	2-18 hr	4.8(3.3-5.5)	44.1(32-50)	14.2(11.0-15.7)	30(27-34)	94(90-100)	B-F,6,7
46	24-48 hr	5.2(4.4-5.8)	50.0(43-59)	15.6(13.7-18.1)	33(27-34)	97(89-102)	B-F,6,7
47	Adult female	6.29	39.8	12.8	21	64	B-F,6,7

/1/ Gestation period = 280 da. /4/ Probably by caesarian section. /5/ Gestation period = 147 da. /6/ Caesarian section. /7/ Gestation period = 114 da. /8/ Gestation period = 31 da.

83. ERYTHROCYTE AND HEMOGLOBIN VALUES IN FETUS, NEWBORN, AND ADULT FEMALE: MAMMALS (Concluded)

Values given for adult female are not necessarily those of the mother. Values in parentheses are ranges and conform, unless otherwise specified, to estimate "c" of the 95% range (cf Introduction).

	Stage of Development	RBC Count millions/cu mm blood	RBC Packed Volume (Hematocrit) ml/100 ml blood	Blood Hb Concentration g/100 ml blood	RBC Hb Content μμg	RBC Volume cu μ	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Rat						
	Fetus at fraction of term[9]						
48	0.6			5.1(5.0-5.3)			D,10
49	0.7			7.6(6.1-9.2)			D,10
50	0.8	0.98(0.70-1.20)	21.0	8.5(7.5-9.3)	52	160	B,C,11;D,10;E,F,7
51	0.9	1.8(1.5-2.1)	40.1(40.0-40.2)	8.2(7.4-9.1)	32.5(31-34)	159(157-160)	B,C,11;D,10;E,F,7
	Newborn						
52	1-7 da	2.0(1.4-2.9)	25.0(18.2-31.0)	8.3(6.3-10.5)	43(31-60)	126(96-172)	B-F,7
53	8-14 da	2.2(1.6-2.8)	20.6(15.1-28.0)	6.6(4.6-9.0)	31(24-36)	92(77-110)	B-F,7
54	Adult female	6.6	39.4	12.8	20	61	B-F,7
	Sheep						
	Fetus at fraction of term[10]						
55	0.2			4.0(2.8-4.8)			D,12
56	0.3			6.9(4.6-8.4)			D,12
57	0.4	1.83(1.58-2.09)	27(25-29)	8.3(6.4-11.2)	40.5	151(119-184)	B,C,E,F,d;D,12
58	0.5			9.2(7.9-10.3)			D,12
59	0.6	5.1	37	10.7(8.7-12.8)	20.5	73	B,C,E,F,d;D,12
60	0.7			11.2(8.8-13.4)			D,12
61	0.8	8.1	41.5	11.9(10.2-13.6)	13.1	48	B,C,E,F,d;D,12
62	0.9	9.9(8.3-11.8)	49(41.54)	12.6(8.5-17.0)	12.8(12.3-13.1)	49(43-55)	B,C,E,F,d;D,12
63	Adult female	11.6	34	11.0	13	30	B-F,13

/9/ Gestation period = 21 da. /10/ Gestation period = 147 da.

Contributors: (a) Barron, D. H., (b) Bethell, F. H., (c) Osgood, E. E., (d) Young, I. M.

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84. ERYTHROCYTE AND HEMOGLOBIN VALUES FROM BIRTH TO MATURITY: MAN

Values are smoothed means from plotted curves. Values in parentheses are ranges and conform, unless otherwise specified, to estimate "c" of the 95% range (cf Introduction).

	Age	RBC Count millions/cu mm blood	RBC Packed Volume (Hematocrit) ml/100 ml blood	Blood Hb Concentration g/100 ml blood	RBC Hb Concentration g/100 ml RBC	RBC Hb Content μμg	RBC Volume cu μ
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	At birth[1]	5.7(4.8-7.1)	56.6	21.5(18.0-27.0)	38.0	38	106
2	First da	5.6(4.7-7.0)	56.1	21.2(17.7-26.5)	37.8	38	106
3	End 1st wk	5.3(4.5-6.4)	52.7	19.6(16.2-25.5)	37.2	37	101
4	End 2nd wk	5.1(4.3-6.0)	49.6	18.0(14.5-24.2)	36.3	35	96
5	End 3rd wk	4.9(4.1-6.0)	46.6	16.6(13.2-23.0)	35.6	34	93
6	End 4th wk	4.7(3.9-5.9)	44.6	15.6(12.0-21.8)	35.0	33	91
7	End 2nd mo	4.5(3.8-5.8)	38.9	13.3(10.8-18.0)	34.2	30	85
8	End 4th mo	4.5(3.8-5.3)	36.5	12.4(10.2-15.0)	34.0	27	79

/1/ Cord clamped after placental separation, averages 560,000 more RBC/cu mm and 2.6g/100 ml more hemoglobin during first week of life than cord clamped immediately after birth. In newborn, heel blood (capillary) higher in RBC and hemoglobin than blood from superior sagittal sinus.

84. ERYTHROCYTE AND HEMOGLOBIN VALUES FROM BIRTH TO MATURITY: MAN (Concluded)

Values are smoothed means from plotted curves. Values in parentheses are ranges and conform, unless otherwise specified, to estimate "c" of the 95% range (cf Introduction).

	Age	RBC Count millions/cu mm blood	RBC Packed Volume (Hematocrit) ml/100 ml blood	Blood Hb Concentration g/100 ml blood	RBC Hb Concentration g/100 ml RBC	RBC Hb Content µµg	RBC Volume cu µ
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
9	End 6th mo	4.6(3.9-5.3)	36.2	12.3(10.0-15.0)	34.0	27	78
10	End 8th mo	4.6(4.0-5.4)	35.8	12.1(9.8-15.0)	33.8	26	77
11	End 10th mo	4.6(4.0-5.5)	35.5	11.9(8.4-14.9)	33.5	26	77
12	End 12th mo	4.6(4.0-5.5)	35.2	11.6(9.0-14.6)	33.0	25	77
13	End 2nd yr	4.7(3.8-5.4)	35.5	11.7(9.2-15.5)	33.0	25	78
14	End 4th yr	4.7(3.8-5.4)	37.1	12.6(9.6-15.5)	34.0	27	80
15	End 6th yr	4.7(3.8-5.4)	37.9	12.7(10.0-15.5)	33.5	27	80
16	End 8th yr	4.7(3.8-5.4)	38.9	12.9(10.3-15.5)	33.2	27	80
17	End 10th yr	4.8(3.8-5.4)	39.0	13.0(10.7-15.5)	33.3	27	80
18	End 12th yr	4.8(3.8-5.4)	39.6	13.4(11.0-16.5)	33.8	28	81
	14 yr and over[2]						
19	Male	5.4(4.6-6.2)[b]	47.0	16.3(14.5-18.1)[b]	33.5	29	87
20	Female	4.8(4.2-5.4)[b]	42.0	14.5(12.3-16.7)[b]	33.5	29	87
21	Average (19 and 20)	5.1	44.5	15.4	33.5	29	87

/2/ See Table 81.

Contributors: (a) Bethell, F. H., (b) De Marsh, Q. B., (c) Diggs, L. W., (d) Glaser, K., (e) Guest, G. M., (f) Mayerson, H. S., (g) Osgood, E. E., (h) Washburn, A. H., (i) Windle, W. F., (j) Wintrobe, M. M.

Reference: Albritton, E. C., "Standard Values in Blood," Philadelphia: W. B. Saunders Co., 1952 (Table 38).

85. ERYTHROCYTE O_2 CONSUMPTION: VERTEBRATES

Values are expressed as µl/mg dry weight/hr and are calculated on the basis of water content of cells being 70% by weight. Chem = chemical, mano = manometric, B = blood, C = cells, D = defibrinated, W-R = washed, buffy coat removed, W-C = washed cells of whole blood, Sus = suspension of RBC, R = Ringer, S = isotonic saline.

	Animal	Temp. of Measurement °C	Method	Blood or Cells: Sample	Blood or Cells: Condition	Q_{O_2}: In Serum	Q_{O_2}: In Ringer or Saline	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Man	37	Chem	B	D		0.015 R	1
2		37	Mano	B	D	0.018	0.017 R	2
3		37	Mano	C	W-R		0.042 R	3
4		37	Mano	C	W-C		0.060 R	4
5	Rabbit	37	Chem	B	D		0.049 R	1
6		25	Chem	B	D	0.220	R	5
7		38	Mano	B	D	0.064	0.028 R	6
8		37	Mano	B	D	0.062		7
9		37	Mano	C	Sus		0.024 R	4
10	Chicken	25	Chem	B	D	0.260		5
11		38	Mano	B	D	0.350	0.210 R	6
12		37	Mano	C	W-C		0.180 R	4
13	Goose	39	Chem	B	D	0.670	0.440 R	1
14		25	Chem	B	D	0.250		5
15		37	Mano	B	D	0.720	0.400 R	8
16	Alligator, American	25	Mano	C	D	0.113	0.067 S	6
17	Snake, garter	25	Mano	C	W-C	0.154	0.081 S	6
18	Snake, water	25	Mano	C	W-C	0.173	0.083 S	6
19	Turtle	25	Mano	C	W-C		0.060 R	4
20	Turtle, Blanding's	25	Mano	C	W-C	0.096	0.067 S	6
21	Turtle, box	25	Mano	C	W-C	0.158	0.081 S	6
22	Turtle, snapper	25	Mano	C	W-C	0.119	0.075 S	6
23	Frog, bull	25	Mano	C	W-C	0.111	0.051 S	6
24	Fish, puffer	20	Mano	C	W-C	0.227		6
25	Fish, sea robin	20	Mano	C	W-C		0.075 S	6
26	Toadfish	20	Mano	C	W-C	0.112		6

Contributors: (a) Hunter, F. R., (b) Ponder, E.

References: [1] Warburg, O., Zschr. physiol. Chem. 59:112, 1909. [2] Harrop, G. A., and Barron, E. S., J. Exp. M. 48:207, 1928. [3] Damble, K., Zschr. ges. exp. Med. 86:594, 1933. [4] Ramsey, R., and Warren, C. O., Jr., Quart. J. Exp. Physiol. 20:213, 1930. [5] Roche, J., and Siegler-Soru, E., Arch. internat. physiol. 31:413, 1929. [6] Tipton, S. R., J. Cellul. Physiol. 3:313, 1933. [7] Nagelein, E., Biochem. Zschr. 158:121, 1925. [8] Horn, Z., ibid 226:297, 1930.

86. ERYTHROCYTE AND HEMOGLOBIN VALUES: VERTEBRATES

Values in parentheses are ranges and conform, unless otherwise specified, to estimate "c" of the 95% range (cf Introduction).

	Animal	RBC Count millions/cu mm blood	RBC Packed Volume (Hematocrit) ml/100 ml blood	Blood Hb Concentration g/100 ml blood	RBC Hb Concentration g/100 ml RBC	RBC Hb Content μμg	RBC Volume cu μ	RBC Diameter[1] (Dry Film) μ	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Mammals								
1	Man, ♂	5.4(4.6-6.2)[b]	47(40-54)[b]	16.3(14.5-18.1)[b]	33.5(27-40)[b]	29(25-34)[b]	87(70-94)[b]	7.5(7.2-7.8)[b]	B,E,1,2;C,2,3;D,4;F,G,2;H,1,5
2	Man, ♀	4.8(4.2-5.4)[b]	42(37-47)[b]	14.5(12.3-16.7)[b]	33.5(30-40)[b]	29(24-33)[b]	87(74-98)[b]	7.5(7.2-7.8)[b]	
3	Buffalo, domestic	6.8	44.3(38-52)	13.0(11.0-15.2)	19.0	29.0	72.0	5.5	6
4	Cat	8.0(6.5-9.5)	40(28-52)	11.2(7.0-15.5)	28(23-31)	14(12-16)	57(51-63)	6.0(5.0-7.0)	7
5	Chimpanzee	5.1(3.4-6.0)	41.6(24-51)	12.3(6.5-15.1)	30.6(29-34)	24.5(20-27)	81.4(70-91)	7.4	8
6	Cow	8.1(6.1-10.7)	40(33-47)[b]	11.5(8.7-14.5)[b]	29.0		50(47-54)	5.9	7
7	Dog	6.3(4.5-8.0)	45.5(38-53)	14.8(11.0-18.0)	33(30-35)	23(21-25)	66(59-68)	7.0(6.2-8.0)	7
8	Goat	16.0(13.3-17.9)	33(27.0-34.6)	10.5(8.8-11.4)	34(33-36)	6.7	19.3	4.0	8
9	Guinea pig	5.6(4.5-7.0)	42(37-47)	14.4(11.0-16.5)	34(33-35)	26.0(24.5-27.5)	77(71-83)	7.4(7.0-7.5)	7
10	Hamster	6.96(3.96-9.96)[b]	49(39-59)[b]	16.0(2.0-30.0)[b]	32.0	23.0	70.0	5.6(5.4-5.8)[b]	9
11	Horse	9.3(8.21-10.35)[b]	33.4(28-42)[b]	11.1(8-14)[b]	33.0			5.5	7
12	Monkey, rhesus	5.2(3.6-6.8)[b]	42(32-52)[b]	12.6(10-16)[b]	30.0				7
13	Mouse	9.3(7.7-12.5)	41.5	14.8(10-19)	36(33-39)	16(15.5-16.5)	49(48-51)	6.0	7
14	Rabbit	5.7(4.5-7.0)	41.5(33-50)	11.9(8.0-15.0)	29(27-31)	21(19-23)	61(60-68)	7.5(6.5-7.5)	7
15	Rat	8.9(7.2-9.6)	46(39-53)	14.8(12.0-17.5)	32(30-35)	17(15-19)	61(57-65)	7.5(6.0-7.5)	7
16	Sheep	10.3(9.4-11.1)	31.7(29.9-33.6)	10.9(10.0-11.8)	34.5(34-35)	11.0	31(30-32)	4.8	8
17	Swine	6.4	39.0(38.0-40.0)	13.7(13.2-14.2)	35.0	21.5(21-22)	61.1(59-63)		8
	Birds								
18	Chicken	2.8(2.0-3.2)	35.6(24.0-43.3)	10.3(7.3-12.9)	29(27-30)	36.6(33-41)	127(120-137)	[11.2 x 6.8]	8
19	Duck[2]	2.8	39.5	14.8(9-21)	38.1	52.1(32-71)		[12.8 x 6.6]	10
20	Goose	2.8(2.6-3.0)	44.7(43.1-46.2)	12.7(11.9-13.4)	28.5(28-29)	45.5(40-51)	160(145-174)	[12.2 x 7.2]	8
21	Pigeon	3.2	42.3	12.8	30.0	40.0	131.0	[13.2 x 6.9]	8
22	Turkey	2.3	38.0	11.2	23.5			[15.5 x 7.5]	10
	Reptiles								
23	Alligator (Alligator mississippiensis)	0.67	30.0	8.2	27.0	123.0	450.0	[23.2 x 12.1]	8
24	Snake, garter (Eutania sirtalis)	1.05(0.71-1.39)	28(19-37)	8.5(5.8-11.3)	31.0	82.0	267(266-268)	[18.1 x 10.3]	8
25	Snake, hognose (Heterodon contortrix)	0.57(0.50-0.63)	18.7(13.3-24.1)	5.6(3.7-7.5)	29.5(28-31)	95.5(74-119)	324.5(266-383)	[16.0 x 9.5]	8
26	Snake, water (Natrix sipedon)	0.77	35.5	10.0	28.0	131.0	465.0	[19.6 x 11.0]	8
27	Terrapin, fresh water	0.74	21.0	6.2	30.0	84.0	284.0	[17 x 12]	8
28	Tortoise (Cistudo carolina)	0.74	22.1	6.2	28.0	85.0	300.0	[18.0 x 8.7]	8
29	Turtle, box	0.65	25(21-27)[b]	7.2(6.1-9.1)[b]	20.6	91.0	442.0	[19 x 9]	11
	Amphibians								
30	Congo snake (Amphiuma means)	0.03	40(39-41)	9.4(7.7-11.0)	24(21-27)	3287(2750-3823)	13,857(13,200-14,513)	[62.5 x 36.3]	8
31	Frog, bull (Rana catesbeiana)	0.44(0.43-0.45)	29.3(26.6-32.0)	7.8(7.4-8.2)	27(26-28)	179(174-184)	670(625-716)	[24.8 x 15.3]	8

32	Hellbender (Cryptobranchus alleghaniensis)	0.07	49.0	13.3	27.0	2010.0	7425.0	[40.5 x 21.0]	8
33	Mud puppy (Necturus maculatus)	0.02	21.4	4.6	22.0	2160.0	10,070.0	[52.8 x 28.2]	8
	Fish								
34	Carp (Cyprinus carpio)	0.84(0.65-1.13)	31.3(21-40)	10.5(9.4-12.4)	33.5	72(63-78)	311(278-340)		12
35	Cod, rock (Gadus callarias)	1.55(1.49-1.60)	29.1(23.8-32.6)	5.9(5.2-6.4)	20(19-22)	38(35-40)	186(159-201)	[12.2 x 9.0]	8
36	Dogfish, smooth (Mustelus laevis)	0.46	23.3	4.6			541.0	[19.1 x 13.8]	13
37	Dogfish, spiney (Squalus acanthas)	0.24	18.9	3.8			820.0	[22.7 x 15.2]	13
38	Eel, common (Anguilla rostrata)	2.48	37.9(36.0-39.8)	9.0(8.0-10.0)	23.5(22-25)	36.5(35-38)	156(141-170)	[13.0 x 8.0]	8
39	Flounder, rusty (Limanda ferruginea)	1.23(0.78-1.61)	14.6(8.4-18.2)	3.2(2.1-4.2)	22.7(19-25)	26.7(26-28)	117.7(107-138)	[10.3 x 7.7]	8
40	Goosefish (Lophius piscatorius)	1.09	16.8	4.3			241.0	[13.3 x 9.6]	13
41	Hogfish (Myxine glutinosa)	0.15(0.12-0.19)	22.2(19.3-27.6)	4.6(4.0-5.7)	21.0	318.3(303-330)	1530(1470-1560)	[26.4 x 18.3]	8
42	Lamprey (Petromyzon marinus)	0.33	23.5	5.8			710.0	14.3	13
43	Mackerel (Scomber scombrus)	3.94(3.68-4.20)	57.5(56-59)	14.9(14.5-15.2)	26.0	37.5(36-39)	146(140-152)	[12.5 x 8.3]	8
44	Perch, white (Morone americana)	3.17(2.70-3.63)	35.3(32.7-37.8)	8.2(6.7-9.7)	23.5(21-26)	26(25-27)	112.5(104-121)	[10.3 x 7.2]	8
45	Pollock (Pollachias virens)	2.64(2.34-2.93)	37.4(35.8-39.0)	7.8(7.4-8.1)	21.0	30(28-32)	143(133-153)	[11.4 x 8.1]	8
46	Sculpin, daddy (Myoxocephalus scorpius)	0.95(0.87-1.03)	20.2(19.8-20.6)	4.4(4.0-4.8)	21.5(20-23)	46.0	213.5(200-227)	[12.4 x 9.5]	8
47	Sculpin, longhorn (M. octodecimspinosus)	1.69(1.34-2.04)	29.4(24.6-34.2)	5.6(5.0-6.2)	19(18-20)	33.5(30-37)	175(167-183)	[11.6 x 8.9]	8
48	Sea robin (Prionotus strigatus)	1.93	22.2	6.2			130.0	[10.4 x 7.3]	13
49	Shark sucker (Echeneis naucrates)	3.75	34.0	10.5			91.0	[10.9 x 7.0]	13
50	Skate, common (Raja erinacea)	0.09(0.07-0.11)	7.2(4.7-9.6)	1.4(0.9-1.8)	19.5(19-20)	148.5(125-172)	778(646-910)	[24.3 x 13.9]	8
51	Skate, barndoor (R. stabuliforis)	0.27	20.0	3.6			727	[21.9 x 15.6]	13
52	Skate, clearnose (R. eglanteria)	0.30	24.0	4.5			823	[23.7 x 14.4]	13
53	Stingray (Dasyatis centrourus)	0.30	19.0	3.0			612	[20.6 x 14.3]	13
54	Trout (Salvelinus fontinalis)	1.01(0.74-1.50)	27.2(22-36)	8.5(6.2-11.5)	31.2	75(61-82)	314(284-348)		12
55	Wrymouth (Cryptacanthodes maculatus)	1.10(0.71-1.48)	21.3(15.4-27.2)	6.4(4.6-8.1)	30.0	60.5(55-66)	200.5(184-217)	[9.0 x 14.0]	8

/1/ Values in brackets are length x width. /2/ As ducks mature, hematologic values progressively increase.

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87. ERYTHROCYTE AND HEMOGLOBIN VALUES AT SEA LEVEL AND ALTITUDE: VERTEBRATES

Values are for acclimatized animals. SL = sea level.

	Animal	Altitude km	RBC Count millions/cu mm blood	RBC Packed Volume (Hematocrit) ml/100 ml blood	O_2 Capacity vol %		Reference
					Blood	RBC	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Llama	SL	12.1	27.5	16.1	58.4	1, 2
2		SL	11.4	38.6	23.5	61.2	2, 3
3		2.8	12.3	28.2	17.1	56.7	2, 3
4		5.3	11.0	25.8	14.9	57.8	2, 3
5	Rabbit	SL	4.55	35.4	15.6	44.1	2, 3
6	Sheep	SL	10.5	35.3	15.9	45.5	2, 3
7		4.7	12.05	50.2	18.9	38.8	2, 3
8	Vicuna	SL	14.9	30.5	17.5	57.1	1, 2
9		4.7	16.6	31.9	18.2	58.5	2, 3
10	Viscacha	3.7	7.12	31.8	14.8	46.6	2, 3
11	Huallata	5.3	3.27	59.1	23.6	40.1	2, 3
12	Ostrich	3.7	2.18	33.8	13.9	41.2	2, 3

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Values are for male residents, unless otherwise indicated. Values in parentheses are ranges and conform, unless otherwise specified, to estimate "c" of the 95% range (cf Introduction). SL = sea level (altitude less than 0.4 km).

	Country	Place	Altitude km	RBC Count millions/cu mm blood	RBC Packed Volume (Hematocrit) ml/100 ml blood	Blood Hb Concentration g/100 ml blood	RBC Hb Content μμg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	U. S. A.	Denver, Colorado	1.5	5.42		16.5	30.4	1
2		Kansas	SL	5.11		15.0	29.4	2
3		New Orleans, Louisiana	SL	5.26		15.6	29.7	3
4		New Orleans, Louisiana	SL	5.85		15.9	27.2	4
5		Omaha, Nebraska	SL	4.69		15.0	32.0	5
6		Portland, Oregon	SL	5.42		15.8	29.2	6
7	Argentina	Buenos Aires	SL	5.30		14.8	27.9	7
8		Buenos Aires	SL	5.50		15.4	28.0	8
9		Mina (Aguilar)	4.5	6.46(5.07-9.43)	59.5(50.5-73.6)	19.4(15.7-24.9)	30.0	9
10		Tucuman	0.4	5.31		16.1	30.3	10
11	Canada	Saskatchewan	0.5	5.52		15.6	28.3	11
12	Denmark	Copenhagen	SL	5.07		15.0	29.6	12
13	Germany	Giessen	SL	4.96		16.0	32.3	13
14	Hawaii	Honolulu	SL	5.08		15.1	29.7	14
15	India	Bombay	SL	5.11		15.4	30.1	15
16		Calcutta	SL	5.36		14.8	27.6	16
17	Mexico	Mexico City	2.3	5.39(4.53-6.17)	51.2(45.0-58.5)	17.7(14.4-20.1)	32.9	17, 18
18		Mexico City	2.3	5.01(4.27-6.01)/1/	45.5(41.5-50.0)/1/	15.2(12.8-17.7)/1/		17
19	Norway	Oslo	SL	5.52		16.2	29.3	19
20	Peru	Lima	SL	5.14		16.0	31.1	20
21		Lima	SL	5.00(4.5-5.6)	45.0(40.0-49.0)	15.1(13.4-16.2)		21
22		Lima	SL	4.87(4.31-5.30)	45.0(41.5-48.5)	15.3(14.0-16.6)		18
23		Morococha	4.5	6.15		20.8	33.8	20
24		Morococha	4.5	6.70(5.30-9.30)	57.0(46.0-71.0)	19.3(17.4-24.0)		21
25		Morococha	4.5	7.88(6.91-8.51)	66.7(58.2-79.2)	22.6(20.7-25.3)		18
26		Oroya	3.7	5.67		18.8	33.2	20
27	South Africa	Johannesburg	1.8	5.99		14.7	24.5	22
28	Switzerland	Zurich	0.5	5.00		15.0	30.0	23

/1/ Female.

Contributors: (a) Dill, D. B., (b) Ebaugh, F. G., Jr.

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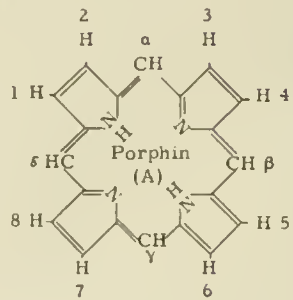
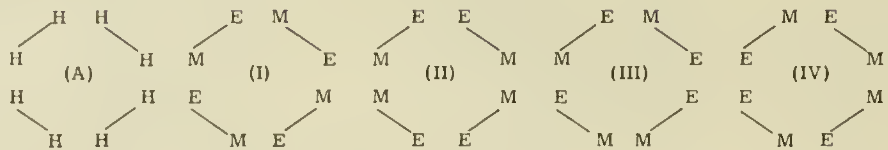
Part I: PORPHYRINS

These pigments are derived from porphin (A) by substitution of the nuclear hydrogen atoms. There are four stereoisomers called "etioporphyrins" (I, II, III, IV) which are used as the basis for classifying naturally occurring porphyrins. The natural porphyrins correspond to etioporphyrins I and III; chlorophylls and hemoglobins are of type III only; free porphyrins are predominately of type III; small quantities of type I occur in physiological condition, great quantities in some pathological states. Substituent groups: A = (-CH_2·COOH); B = (-CHO); M = (-CH_3); P = (-CH_2·CH_2·COOH); V = (-CH:CH_2).

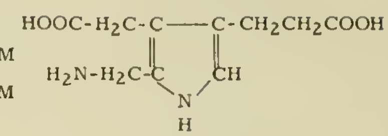


Porphin

Etioporphyrins



Porphyrin Precursor
(Porphobilinogen)



(See Line 1)

	Substituents in Positions[1] 1	2	3	4	5	6	7	8	Physical and Chemical Properties[2,3]	Spectral Characteristics, λ maximum in mμ[4,5] Solvent	I	II	III	IV	Soret	Occurrence in Nature	Reference
	(A)								(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Porphobilinogen ($C_{10}H_{14}O_4N_2$)																1-4
1	A	P	-	-	-	-	-	-	MP hydrochloride = 165-170°C, decomposition; COOH No. = 2; colorless.	2.5 N HCl Acetic-HCl		552[6] 555[7]				Precursor of heme biosynthesis; in acute hepatic porphyria of man and experimental porphyria of animals, in urine and liver.	A, B, a; C, E, 1-3, 5-7; I, 1-3, 8-10
	Uroporphyrin I ($C_{40}H_{38}O_{16}N_4$)																12, 13, 52
2	A	P	A	P	A	P	A	P	MP me. est. = 293°C; HCl No. me. est. = 7[8]; COOH No. = 8.	0.1 N NaOH 25% HCl 0.5 N HCl Ester in chloroform	612 597(577) 626	560.5 553.5 570.5	539 536	504 501	 410.5 405[9] 408	By-product of heme biosynthesis. Traces in normal urine, somewhat more in some diseases, much more in congenital erythropoietic porphyria of man and animals. In mollusk shells and epidermal plant cells.	A, a; B, 14; C-H, 12, 15-17; I, 12, 15, 18-24
	Uroporphyrin III ($C_{40}H_{38}O_{16}N_4$)																13,14,23,25,26
3	A	P	A	P	A	P	P	A	MP me. est. = 264°C; HCl No. me. est. = 7[8]; COOH No. = 8.	0.1 N NaOH 25% HCl 0.5 N HCl Ester in chloroform	612 597(577) 626	560.5 553.5 570.5	539 536	504 501	 410.5 405[9] 408	By-product of heme biosynthesis. Formed from porphobilinogen, in vitro and in vivo. In urine of man in hepatic porphyria and of animals in experimental porphyria; some also in lead poisoning. Turacin, in feathers of the Turaco bird, is Cu complex of uroporphyrin I or III.	A, a; B, 14; C-H, 12, 15-17; I, 1-3, 8-11, 14, 15, 27-35

										Coproporphyrin I ($C_{36}H_{38}O_8N_4$)							12
4	M	P	M	P	M	P	M	P	MP me. est. = 250-258°C; HCl No. me. est. = 1.5; HCl No. f.a. = 0.1; COOH No. = 4.	0.1 N NaOH	617.5	565.5-568.5	538.5	504		By-product of heme biosynthesis. Traces widespread in animals, plants, microorganisms. In feces, urine, erythrocytes, bile, yeast, root nodules. Larger amounts in porphyrias and porphyrinurias.	A, a; B, 23; C-H, 12, 15, 16, 36-38; I, 12, 15, 23 27-30
										25% HCl	594(575)	551			406		
										0.5 N HCl	591	548			401[10]		
										Ether/acetic	624	568	529	495			
										Ester in chloroform	622.5	568	533	499	405		
										Coproporphyrin III ($C_{36}H_{38}O_8N_4$)							12
5	M	P	M	P	M	P	P	M	MP me. est. = 150-160°C, remelts at 174-181°C; HCl No. me. est. = 1.5; HCl No. f.a. = 0.1; COOH No. = 4.	0.1 N NaOH	617.5	565.5-568.5	538.5	504		Often together with coproporphyrin I, predominant in lead and other toxic porphyrinurias. In central nervous system, in birds' feathers and hedgehog spines, and in bacteria.	A, a; B, 23, 39; C-H, 12, 15, 16, 36-39; I, 15, 16, 23, 27-30
										25% HCl	594(575)	551			406		
										0.5 N HCl	591	548			401[10]		
										Ether/acetic	624	568	529	495			
										Ester in chloroform	622.5	568	533	499	405		
										Protoporphyrin IX ($C_{34}H_{34}O_4N_4$)							12
6	M	V	M	V	M	P	P	M	MP me. est. = 230-232°C; HCl No. me. est. = 5.5; HCl No. f.a. = 2.5; COOH No. = 2.	0.1 N NaOH	642	591	540	Indistinct		Component of hemoglobin, myoglobin, catalase, cytochrome-b, and some peroxidases. Free in erythrocytes, feces, chloroma, Harderian glands of rodents, birds' eggshells, earthworms, echinoderms, and protozoa. As Mg complex in mutants of alga *Chlorella*.	A, a; B, 40; C-H, 15, 16, 41; I, 12, 16, 23, 42, 43
										25% HCl	602.5(582)	557			411		
										5% HCl					407[11]		
										Ether/acetic	632.5	576	537	502			
										Chloroform	630.5	578-574[12]	541	507			
										Chlorocruoroporphyrin (Spirographis) ($C_{33}H_{32}O_5N_4$)							12, 40
7	M	B	M	V	M	P	P	M	MP me. est. = 278-285°C; HCl No. f.a. = 5[8]; COOH No. = 2.	20% HCl	615.2	564.3				Component of chlorocruorin, blood pigment of Sabellid worms. Not found as free porphyrin.	A, a; B, 12-40; C-H, 12, 40, 44; I, 45
										Ether/acetic	643	581	555	514.5			
										Ester in chloroform	644	584	558.5	518.5			
										Porphyrin a (cytoporphyrin) ($C_{47}H_{60}O_6N_4$)?							46-49
8	Probably 1B, 3M, 2P, one long alkyl side chain, one double bond in side chain								HCl No. f.a. = 15[8]; COOH No. = 2.	25% HCl	619	564.5(528)				Component of cytochrome oxidase (cytochrome-a_3) and cytochromes a and a_1. Not found as free porphyrin.	A, 47-49; B, 49; C-H, 48; I, 47, 50, 51
										Ether	647	583	558.5	517	412		
										Chloroform	646	584.5	563.5	520	418.5		

/1/ Letters in the columns refer to substituents (abbreviated as per code) appearing in the position indicated by column number (numbers correspond to those in reference structural formula). /2/ All porphyrins show a strongly red fluorescence in Wood's light, both in acid and alkaline solutions and in many neutral solutions. /3/ Abbreviations: est. = ester; f.a. = free acid; me. = methyl; MP = melting point. /4/ λ maximum in mμ = wave length of maximum absorption; $E^{1\%}_{1\,cm}$ = extinction coefficients of 1% solutions of 1 cm thickness. /5/ Free porphyrin and its ester give the same bands in the same solvent; figures in parentheses are weak bands. /6/ Ehrlich aldehyde dye, $E^{1\%}_{1\,cm}$ = 708. /7/ Ehrlich aldehyde dye, $E^{1\%}_{1\,cm}$ = 1136. /8/ Approximate. /9/ $E^{1\%}_{1\,cm}$ = 6500. /10/ $E^{1\%}_{1\,cm}$ = 6670. /11/ $E^{1\%}_{1\,cm}$ = 4900. /12/ The second band is asymmetric, and its position depends on the concentration of the solution.

Contributors: (a) Lemberg, R., (b) Rossi-Fanelli, A., (c) Schmid, R.

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Part II: IRON PORPHYRINS

	Substance (A)	General Nature (B)	Physical and Chemical Properties[1] (C)	Spectral Characteristics λ maximum in $m\mu$[2] (D)	Remarks (E)	Reference (F)
				Heme Compounds		
1	Hematin (hydroxyhemin) ($C_{34}H_{35}O_5N_4Fe$) and anhydrides	Fe^{+++} complex of protoporphyrin; moderately stable.	Soluble in alkali; slightly soluble in ether.	10% NaOH: 580(10.5) Alcoholic $NaHCO_3$: 590 402.5(79.5) "Acid hematin" in ether: 650 Stoke's reagent produces hemochrome bands.	Prosthetic group of methemoglobin, catalase, horseradish peroxidase. Produced by atmospheric oxidation of heme or neutralization of hemin. As alteration product of hemoglobin in the leech, in malarial parasites, and produced by certain bacteria. In blood extravasations and in the plasma in pathological conditions (hematinemia); present as methemalbumin in urine, bile, and feces in pathological conditions.	A,1,2;B-C, a;D,2;E, 1-4
2	Heme (protoheme IX) ($C_{34}H_{32}O_4N_4Fe$)	Fe^{++} complex of protoporphyrin; easily autooxidized to hematin.	Soluble in alkali; Fe removed by dilute HCl in glacial acetic acid.	Phosphate buffer pH 7.0: 575-550(5.5) 415[s]	Prosthetic group of hemoglobin, myohemoglobin, and ferrocytochrome-b. Combines with nitrogenous bases to form hemochromes (hemochromogens).	A,1,2;B,C, E,a;D,2

3	Hemin (chlorohemin) ($C_{34}H_{32}O_4N_4FeCl$)	Crystalline chloride of hematin; stable.	Brown-black crystals sintering at 240°C, melting at 300°C; soluble in dilute alkali, pyridine, organic bases; slightly soluble in glacial acetic acid, chloroform; insoluble in water.	Acetic acid: Alcohol HCl: Converted to hemochrome by pyridine + dithionite.	630-635 540 510 400 [s] 400 [s] (131-151)	Not found in nature. Hemin crystals are used for identification of blood.	A,1,2;B, C,E,a; D,2
4	Methemalbumin (ferrihemalbumin)	Compound of hematin with serum albumin, probably by electrostatic linkages. Iron is in Fe^{+++} state.	Soluble in water like serum albumin.	Fe^{+++}: Fe^{++}: Absorption band abolished by dithionate (cf sulfhemoglobin).	623 540 500 570 530	Found in plasma under conditions of rapid hemolysis as pathological product.	A,E,2,5; B-D,a
5	Pyridine hemochrome (hemochromogen) ($C_{34}H_{32}O_4N_4Fe)(C_5H_5N)_2$	Compound of heme (Fe^{++}) with pyridine bound to iron by coordinate linkages. Autooxidizable, but moderately stable; diamagnetic.	Soluble in dilute pyridine, alkali, and pyridine-glacial acetic acid.		558(31-35) 526(16.2)	The term "hemochromogen" or "hemochrome" is used generically for compounds of heme with nitrogenous bases or proteins. All have characteristic spectra, but band positions may differ by 10-20 mμ with different N-compounds.	A,D,2;B, C,E,a
6	Chlorocruorohemin (Spirographis hemin) ($C_{33}H_{30}O_5N_4FeCl$)	Chlorohemin of chlorocruoroporphyrin (spirographis porphyrin).	Same as hemin (above).	Pyridine hemochrome:	582 538	Chlorocruoroheme (Fe^{++}) is the prosthetic group of chlorocruorin.	A,1;B,C,E, a;D,2
7	Hemin-a (cytohemin) ($C_{47}H_{58}O_6N_4FeCl$)?	Chlorohemin of porphyrin-a.	Soluble in organic solvents (except light petroleum), dilute alkali.	Pyridine hemochrome: (no β-band) CO-heme:	587 430 603 423	Prosthetic group of cytochromes a_3, a, and a_1 but not a_2.	A,6-8;B, C,a;D, 7;E,6
				Hemoglobin Compounds			
8	Hemoglobin (Hb)	Four hemes bound to globin; MW 67,000; iron in Fe^{++} state. Some invertebrate hemoglobins (erythrocruorins) have a far higher MW and lower	Easily soluble in water, less in strong phosphate buffer or ammonium sulfate solution; red-purple color.		555(12.9-13.6) 430 [s] (118-134)	O_2 carrier in red corpuscles of vertebrates and some invertebrates; free in plasma of some invertebrates. In root nodules of plants, protozoa, and some yeasts and bacteria. Species-specific; some species contain more than one hemoglobin. In man, fetal Hb (HbF) differs from normal adult (HbA); several genetic alleles to HbA are known: S, B, C, D, E, F,	A,2,9;B, D,2;C, a;E,2, 10-13

/1/ MW = molecular weight; E_0' = oxidation-reduction potential. /2/ λ maximum in mμ = wave length of maximum absorption; figures in parentheses are $E^{mM}_{1\,cm}$, i.e., extinction coefficients of millimolar solutions of 1 cm thickness; [s] = Soret band.

Part II: IRON PORPHYRINS (Continued)

	Substance	General Nature	Physical and Chemical Properties[1]	Spectral Characteristics λ maximum in $m\mu$[2]	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
	Hemoglobin Compounds (continued)					
	Hemoglobin (Hb) (concluded)	isoelectric point than mammalian hemoglobin.			G, H, I, J. Also involved in CO_2 transport.	
9	Oxyhemoglobin (HbO_2)	Compound with one O_2 reversibly bound per heme; available physiologically; iron in Fe^{++} state. At low pO_2 intermediates between $(Hb)_4(O_2)_4$ and $(Hb)_4$, such as $(Hb)_4(O_2)_3$ or $(Hb)_4(O_2)$, exist, which cause the O_2 dissociation curve to be sigmoid (cf myohemoglobins).	Bright red color, yellow in very dilute solution (cf HbCO).	577(15.1-16.2) 540-542 (14.2-15.3) 412-415[s] (125-128.5)	Predominant in arterial blood, mixed with Hb in venous blood; 1 g Hb binds 1.34 ml O_2 at 0°C, 760 mm Hg and contains 0.335% iron.	A,2,9;B, C,E,a; D,2
10	Carboxyhemoglobin (HbCO)	Compound of Hb with CO reversibly bound to heme and dissociable by light; iron in Fe^{++} state. Affinity of Hb for CO approximately 400 x that for O_2; intermediates between $(Hb)_4(CO)_4$ and $(Hb)_4$ at very low pCO.	Bright red; pink in very dilute solution (cf HbO_2).	568-572 (13.7-15.0) 538-540 (14.1-15.3) 418[s] (154)	Found in blood in CO poisoning, in small percentage in normal blood. Stable to reducing agents.	A,D,2;B, C,E,a

11	Methemoglobin (MetHb)	Iron in Fe^{+++} state. MetHb forms compounds with CN^-, F^-, N_3^-, NO, H_2O_2.	Brown to brown-red color.	"Acid MetHb": 630(3.7-3.8), 500(9.5), 405-407 [s] (134-154) Alkaline MetHb: 577(9.5), 540(9.7), 411 [s] (71-90) Stoke's reagent produces spectrum of Hb (cf hematin); the 630 band of "acid MetHb" disappears on addition of Na_2CO_3 or cyanide and on addition of dithionite.	Small amounts normally present in blood. Larger amounts formed by auto-oxidation of HbO_2, particularly at low pH, and by oxidation with ferricyanide, nitrite, chlorate; formed in circulating blood by aromatic amines and nitro compounds, sulfonamides, and some poisons. Erythrocytes possess mechanisms for reduction of MetHb to Hb, which do not function in idiopathic familial methemoglobinemia.	A,B,D,2; C,a;E, 2,14,15
12	Sulfhemoglobin (HbS)	Formed by treatment of HbO_2 solutions with H_2S; solution still contains Hb. Globin and prosthetic group of unknown strucure which can be retransformed into protoheme.	Purplish-green color.	Fe^{++}: 620(11-13) FeCO: 616(16) Band stable in presence of dithionite (cf methemalbumin and methemoglobin), Na_2CO_3, and cyanide. NaOH + dithionite = protohemochrome (cf choleglobin).	Pathological product in erythrocytes, formed by the action of intestinal H_2S on HbO_2, catalyzed by aromatic amines, e.g., phenacetin; also found in septicemias. Red corpuscles containing sulfhemoglobin appear to have a normal life span.	A, E, 2; B-D, a
13	Choleglobin	Formed by coupled oxidation of Hb with ascorbic acid. Globin + prosthetic group derived from protoheme by oxidation (probably mixture of choleheme with intact C_{34} ring and verdoheme with an oxygen atom replacing one methene bridge).	Green color; solubility similar to that of Hb, but more easily denatured.	Fe^{++}: 629 FeCO: 628 Na + dithionite = cholehemochrome: 619 (cf sulfhemoglobin)	May be an intermediate formation of bile pigments from hemoglobin. Formed by the action of some bacteria on hemoglobin ("viridans effect"). Found in erythrocytes after phenylhydrazine administration.	A,2,16, 17;B,D, E,2;C, a
14	Myohemoglobin (MHb) or Myoglobin (Mb)	Heme + globin (different from globin in Hb); contains one heme only at MW of 18,500.	MbCO (of horse) is more soluble than HbCO in strong phosphate buffer or ammonium sulfate solution. Alkali	Fe^{++}: 555, 435 Mb differs from Hb particularly in the position of the α-band of myo-oxyhemoglobin, 582 mμ and myo-carboxyhemoglobin, 579 mμ	O_2 carrier between oxyhemoglobin and intracellular respiratory enzymes; O_2 store under certain conditions. In red muscles of vertebrates, particularly diving animals, also in some invertebrate	A,2,14,18; B,19;C, a;D,14, 20,21; E,2,14, 22-25

/1/ MW = molecular weight; E_0' = oxidation-reduction potential. /2/ λ maximum in mμ = wave length of maximum absorption; figures in parentheses are $E^{mM}_{1\,cm}$, i.e., extinction coefficients of millimolar solutions of 1 cm thickness; [s] = Soret band.

Part II: IRON PORPHYRINS (Continued)

	Substance	General Nature	Physical and Chemical Properties[1]	Spectral Characteristics λ maximum in mμ[2]	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
	Hemoglobin Compounds (concluded)					
	Myohemoglobin (MHb) or Myoglobin (Mb) (concluded)	O_2 affinity greater than that of Hb; O_2 dissociation curve hyperbolic; Fe^{++} more readily oxidized to Fe^{+++} by O_2 than in Hb. Derivatives similar to those of Hb.	resistance greater than that of Hb.		muscles. Species-specific, but more than one kind may be present in muscles of one and the same species. Pathologically in urine of crush injury victims and in certain diseases of man and horse.	23,24, 25
15	Chlorocruorin (Ch)	Globin of high MW and low isoelectric point + several groups of chlorocruoroheme.	MW approximately 3,000,000. Green color.	Fe^{++}: 574 (broad band) FeO_2: 604, 560 FeCO: 600, 507	Blood pigments of some annelids (Polychaeta), e.g., Spirographis, a marine worm. Free in plasma.	A,D,2;B, C,E,a
	Hematin Enzymes					
16	Catalase	Compound of protohematin (iron in Fe^{+++} state) with protein apoenzyme. Iron is not reduced by dithionite, but is reduced by H_2O_2 in the presence of azide. Liver catalases often contain chole- and verdohematin. Combines with H_2O_2, the green "primary" complex being active.	MW = 225,000-250,000 with four hematins per mole; rather stable, crystallizable proteins. Although no reversible splitting of hematin from the apoenzyme has been achieved, the apoenzyme is present in some bacteria lacking hematin, but requiring it for growth.	629-622(10.8) 544-536 506.5-500 409-400[s] (145)	Decomposes H_2O_2 to H_2O and O_2, but also acts as peroxidase on certain substrates, e.g., alcohol. Present in all aerobic cells, highly concentrated in some animal tissues (red cells, liver) and in some bacteria, absent in some strict anaerobes and in a few facultative anaerobes. Catalytic activity inhibited by cyanide, H_2S, hydroxylamine, azide, and other compounds.	A,2, 26-29; B,2, 28-32; C,33;D, 2;E,2, 27-29, 34-37

17	Peroxidase	Prosthetic group, (1) in horseradish, yeast cytochrome-c, and other plant peroxidases = protohematin which can be reversibly split from apoenzyme, iron in Fe^{+++} state; (2) in lactoperoxidase = hematin of a ketonylporphyrin firmly bound to apoenzyme; (3) in myeloperoxidase = hematin similar to cholehematin firmly bound to apoenzyme. Iron is reduced to Fe^{++} by dithionite. The red "secondary" complex probably containing ferryl iron $(FeO)^{++}$ is active.	MW of horseradish peroxidase = 44,000 with one hematin group. MW of lactoperoxidase = 93,000 with one hematin group. These two peroxidases are red, while myeloperoxidase is green.	Horseradish peroxidase Fe^{+++}: Fe^{++}: Lactoperoxidase: Fe^{+++}: Fe^{++}: Myeloperoxidase: Fe^{+++}: Fe^{++}:	 645(12) 583 548 498 410[s] (125) 594 (weak) 558 640 (weak) 600(7.6) 500(11.4) 412[s] (109) 645 (weak) 600 566 690(3.5) 625(6.5) 570(11.0) 495 (weak) 430(70) 637(17.3) 590(11.0) 475(65-80)	Catalyzes the oxidation by H_2O_2 of a large variety of subtrates, e.g., phenols and polyphenols, aromatic amines, cytochrome-c, ascorbic acid, indole acetic acid. With some substrates, e.g., dihydroxyfumaric acid, the enzyme can act as oxidase. Widespread in plants and present in some animal tissues. Lactoperoxidase occurs in milk, myeloperoxidase in leucocytes.	A,2,26,27; B,2,17, 38-44; C,a; D,E,2
18	Cytochromes of type a a_3 a a_1 a_2	Prosthetic group heme-a (cytoheme, No. 7). a_3 and a_1 react with O_2 and CO, a does not. a_3 and a have not been separated yet. Prosthetic group of a_2	Bound to particulate matter; soluble only as complex with cholate, desoxycholate, digitonin, and similar compounds.	Fe^{++} of a_3 + a: FeCO of a_3: Fe^{++} of a_1: Fe^{++} of a_2: Fe^{++} of a_2CO: Fe^{+++} of a_2:	605-600 (due to a_3 + a) 445[s] (due mainly to a_3) 590 430 590 435-440 630 634 645	Mitochondria of animals and plants contain the a_3 + a system as terminal oxidase; also found in yeasts and some bacteria. Inhibited by cyanide, azide, and CO; CO inhibition is abolished by light ("photochemical absorption spectrum"). Only a_3 reacts directly with O_2 and CO, while a may act as electron carrier between Fe^{+++} a_3 and Fe^{++} cytochrome-c. Some bacteria	A,2,45;B, 46,47; C,D,a; E,32,48

/1/ MW = molecular weight; E'_0 = oxidation-reduction potential. /2/ λ maximum in $m\mu$ = wave length of maximum absorption; figures in parentheses are $E^{mM}_{1\,cm}$, i.e., extinction coefficients of millimolar solutions of 1 cm thickness; [s] = Soret band.

	Substance	General Nature	Physical and Chemical Properties[1]	Spectral Characteristics λ maximum in mμ[2]	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
	Hematin Enzymes (Continued)					
	Cytochromes of type a a_3 a a_1 a_2 (concluded)	quite different, iron complex of dihydroporphyrin (chlorin) without formyl side chain.			contain the cytochrome a_2 + a_1 system instead of the a_3 + a system.	
19	Cytochromes of type b b b_1 b_2 b_3 b_5 b_6 b_7	Prosthetic group protoheme changing valence between Fe^{++} and Fe^{+++} in reaction. Protohemin can be split off from apoenzyme. Cytochrome-b_2 probably also contains flavin and non-heme iron.	Cytochrome-b of mitochondria and b_1 of some bacteria are bound to particulate matter. E_0' (pH 7, 30°C) = 0 (approx.). b_2 can be brought into aqueous solution and has been obtained in crystalline form. b_3 of plant microsomes and b_5 of animal microsomes (liver, silkworm midgut) have similar properties. b_6 of chloroplasts and b_7 of the spadix of *Arum* are soluble. "b_4" of halotolerant bacteria perhaps belongs to cytochromes of type c.	Fe^{++} of b: 565-563; 528-530; 430 b_1: 560-558 b_2: 556-557 b_3: 560 b_5: 557 b_6: 563 b_7: 560	Cytochrome-b_2 is the lactic dehydrogenase of yeast. The role of cytochromes b and b_1 is not yet fully understood; they probably act as electron carriers between enzyme-activated substrates or flavoproteins and cytochrome-c. Cytochromes b_3, b_5, and b_7 may react directly with O_2 or with still unknown oxidases. A protoheme compound acts as terminal oxidase in a *Micrococcus* and perhaps in other bacteria. Helicorubin and cytochrome-h of snails belong to this class.	A,2,45;B, 49,50,90, 91;C,49-64,90-93;D,a; E,12,13, 65,66
20	Cytochromes of type c c c_1 f c_2 c_3 c_4 c_5 and other bacterial cytochromes	Prosthetic group of cytochrome-c is a derivative of hematoheme, with thioether bridges between $-CH(CH_3)-$ side chains of the porphyrin and cysteine groups in the	Cytochrome-c, MW = 12,000-13,000; water soluble, resistant to heat and moderately resistant to strong acids, not autooxidizable and does not react with CO. E_0' (pH 7, 30°C) = 0.25 volts. Several species-specific cytochromes c (pig and ox heart,	Fe^{++} cytochrome-c: 550(26-28); 522(15.5-16.9); 415[s] (143); 345 Fe^{+++} cytochrome-c: 565 (indistinct); 530(9.4-9.7); 407[s] (112); 346 Fe^{++} of c_1: 552 f: 555 c_2: 550-552; 520-523	Most animal and plant cells contain cytochrome-c in their mitochondria as essential electron carrier. Also found in yeasts and many aerobic bacteria, while other related cytochromes of type c are found in photosynthetic and anaerobic bacteria. Some, e.g., c_3, c_4, c_5, do not react with the mammalian cytochrome a_3 + a system. Cytochrome-f is present in chloroplasts and is probably essential for photosynthesis. Cytochrome-c_2 is found	A,2,45,53, 54,67-75,94-96;B,2, 76-81; C,82-85;D,a; E,12,13, 86-89, 94-96

	protein, providing a firm linkage which can, however, be broken by Ag salts. A similar linkage appears to be present in cytochromes $\underline{c}_2$ and $\underline{f}$. While the other bacterial cytochromes have bands in the region of cytochrome-$\underline{c}$, their structure has not yet been established. They may belong to cytochrome-$\underline{b}$ or to a new class between cytochromes $\underline{b}$ and $\underline{c}$.	penguin, fish, yeast) have been crystallized. Cytochrome-$\underline{f}$, MW $\sim$ 110,000; E_0' (pH 7, 30°C) = 0.365 volts. Cytochrome-$\underline{c}_3$, MW approximately 12,500 but with two heme groups; E_0' (pH 7, 30°C) = -0.20 volts.	$\underline{c}_3$: 553 525 419 $\underline{c}_4$: 551 522 416 $\underline{c}_5$: 555	in photosynthetic bacteria and is active in their photochemical reaction mechanism. Cytochrome-$\underline{c}_3$ is found in the anaerobic sulfate reducer, Desulfovibrio desulfuricans, and cytochromes $\underline{c}_4$ and $\underline{c}_5$, in Azobacter vinelandii. Cytochrome-$\underline{c}_1$ accompanies cytochrome-$\underline{c}$ and is also found in plant microsomes.	

/1/ MW = molecular weight; E_0' = oxidation-reduction potential. /2/ λ maximum in mμ = wave length of maximum absorption; figures in parentheses are $E^{mM}_{1\,cm}$, i.e., extinction coefficients of millimolar solutions of 1 cm thickness; [s] = Soret band.

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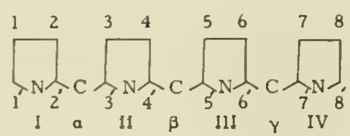
Part III: BILIRUBINOIDS AND RELATED DIPYRRYL COMPOUNDS



(A)

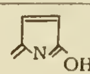
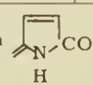
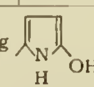
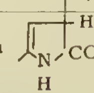
These are derivatives of the tetrapyrrolic structure (A) formed by varying degrees of oxidation, and substitution of the nuclear H atoms 1, 2, 3, 4, 5, 6, 7, 8. While formula (A) describes the bilirubinoids as linear tetrapyrrolic chains with terminal hydroxyl groups, their structure is more correctly described as that of a tetrapyrrolic ring closed by a hydrogen bond between oxygen atoms (N>CO·HOC<N). All natural members are derived from Fischer's protoporphyrin IX by fission at the α-methene link. They are therefore known as Bilirubinoids IX-α.

The main reactions are as follows:

G = Gmelin reaction: given by bilirubins; the later stages also by biliverdins and bilipurpurins.
D = Diazo reaction: depending on the splitting of the molecule at a central $-CH_2-$ group.
E = Ehrlich reaction: characteristic of bilanes.
P = Pentdyopent reaction: given by most bile pigments, hematin compounds and dipyrryl methenes.
S = Schlesinger reaction: given by dipyrryl methenes.
F = Ferric chloride reaction: given by all except trienes and more highly oxidized pigments, and except tetrahydromesobilane and -bilene.

Substituent groups: E = $(-CH_2CH_3)$; H, H_2 = hydrogen; M = $(-CH_3)$; OH = hydroxyl; P = $(-CH_2 \cdot CH_2 \cdot COOH)$; V = $(-CH{:}CH_2)$.
+ = positive reaction; (+) = non-characteristic reaction; - = negative reaction.

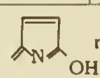
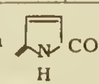
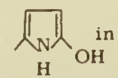
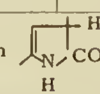
	Substance	Substituents in Positions[1] 1 / 1' / α	2 / 2' / β	3 / 3' / γ	4 / 4'	5 / 5' / I	6 / 6' / II	7 / 7' / III	8 / 8' / IV	Number of Pyrrole Nuclei in Chromophor, and Color	Other Physical and Chemical Properties[2]	Spectral Characteristics λ maximum in mμ[2, 3]	Reactions G	D	E	P	S	F	Remarks	Reference
	(A)	(B)								(C)	(D)	(E)	(F)						(G)	(H)
	Bilanes and Hydrobilanes																			
1	Mesobilane[4] (mesobilirubinogen; i-urobilinogen; urobilinogen IX-α) ($C_{33}H_{44}O_6N_4$)	M	E	M	P	P	M	M	E	1 Colorless	Cryst.; MP = 199°C; s. al., am. al., chl., eth., pet. eth., dil. alk; i.w.	Red pigment (s. chl.) on treatment with Ehrlich aldehyde: approximately 560 mμ (64.5).	-	-	+	+	-	+	Traces in normal, more in pathological urine, bile, and feces. Distinguished from 2 (below) by F reaction or by violet pigment (bands at 665, 600, 510 mμ) on warming with NaOH-$CuSO_4$.	A,1-4; B-D,F, a;E,4; G,1-9
		HO	-	-	-	-	-	-	OH											
		H_2	H_2	H_2		H	H	H	H											
2	Tetrahydro-mesobilane[4] (stercobilinogen; l-urobilinogen) ($C_{33}H_{48}O_6N_4$)	M,H	E,H	M	P	P	M	M,H	E,H	1 Colorless	Non-cryst.; MP = 125-150°C; s. al., am. al., chl., eth., pet. eth., dil. alk.; i. w. $[\alpha]_D^{20}$ = -17°		-	-	+	-	-	-	Main excretory product of hemoglobin in most vertebrates. Distinguished from 1 (above) by negative F reaction, or NaOH-$CuSO_4$ reaction (only one band at 530-500 mu).	A,1,2,10, 11;B,C, F,G,a; D,12;E, 4
		O=	H	-	-	-	-	H	=O											
		H_2	H_2	H_2		H	H	H	H											
3	d-Urobilinogen[4] ($C_{33}N_{42}O_6N_4$)?	Unknown								1 Colorless	Cryst. needles from eth. ac.; MP = 142-175°C; s. chl., eth. acet., bz., glac. ac. a., al., dil. alk.; sl. s. eth. ac., pet. eth.; i. w. $[\alpha]_D^{20}$ = +74°	Red pigment (s. chl.) on treatment with Ehrlich aldehyde.	-	-	+	?	-	(+)	Formed in infected bile passages and in the intestine during ingestion of broad spectrum antibiotics (tetracyclines).	A,G,7,12; B,C,E, F,a;D, 12

/1/ A ring  may be present in the prototropic form , and a ring  in the form . /2/ Abbreviations: ac. a = acetic acid; acet. = acetone; al. = alcohol; alk. = alkali(ne); am. = amyl; bz. = benzene; chl. = chloroform; cryst. = crystal(line); dil. = dilute; dimeth. = dimethyl; est. = ester; eth. = ether; eth. ac. = ethyl acetate; glac. = glacial; grn. = green; i. = insoluble; MP = melting point; me. = methyl; or. = orange; pet. = petroleum; pyr. = pyridine; sl. = slightly; s. = soluble; w. = water; yel. = yellow. $[\alpha]_D^{20}$ = optical rotation at 20°C. /3/ λ maximum in mμ = wave length of maximum absorption; figures in parentheses are $E_{1\,cm}^{mM}$, i.e., extinction coefficients of millimolar solution of 1 cm thickness. /4/ The nomenclature is misleading. "Stercobilin" and "stercobilinogen," as well as "urobilin" and "urobilinogen," occur in feces and urine. All six compounds (1-6), not only 1 and 4, belong to pigment type IX-α. l-, d-, and i- (inactive) refer to the optical rotations of the bilenes (4-6), but these three compounds are not stereochemical isomers.

Part III: BILIRUBINOIDS AND RELATED DIPYRRYL COMPOUNDS (Continued)

	Substance	Substituents in Positions[1] 1 2 3 4 5 6 7 8 1' 2' 3' 4' 5' 6' 7' 8' α β γ I II III IV	Number of Pyrrole Nuclei in Chromophor, and Color	Other Physical and Chemical Properties[2]	Spectral Characteristics λ maximum in $m\mu$[2, 3]	Reactions G D E P S F	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
				Bilenes and Hydrobilenes				
4	Mesobilene[4] (urobilin IX-a; i-urobilin) ($C_{33}H_{42}O_6N_4$)	M E M P P M M E HO - - - - - - OH H_2 H H_2 H H - H	2 Yellow	Reddish-yel. cryst.; MP = 177°C[5]; HCl = 162°C[5]; MP = 190°C[6]; HCl = 199°C[6]; s. al., am. al., chl., dil. alk.; sl. s. eth.; i. w.	Dioxane: 452(25.1) 330(3.6) Dioxane-HCl: 495.2 Alcohol-HCl: 490(50.1) 375(7.4) Zn complex in me. al.: 509.5	- - - + + +	Oxidation product of 1 (above). Distinguished from 5 (below) by positive F and P reactions, optical inactivity and band position in alcohol-HCl in reversion spectroscope.	A,1,2;B C,F,G, a;D,1, 12,13; E,2,12
5	Tetrahydro-mesobilene[4] (stercobilin; l-urobilin) ($C_{33}H_{46}O_6N_4$)	M,H E,H M P P M M,H E,H O= H - - - - H =O H_2 H H_2 H H - H	2 Yellow	Or. cryst.; MP = 236°C; HCl = 162°C; s. al., am. al., chl., dil. alk.; sl. s. eth.; i. w.	Dioxane: 456(33.0) Dioxane-HCl: 492.7 Alcohol-HCl: 488(55.0) 372(8.5) Zn complex in al.: 506.5 Cu complex in al.: 515 $[\alpha]^{20}_{D}$ free: 320 HCl: -3800	- - - - + -	Oxidation product of 2 (above). Distinguished from 4 (above) by negative F and P reactions, optical activity (levorotatory), and band position in alcohol-HCl.	A,1,2,10, 11;B,C, F,G,a; D,12;E, 1,2,12
6	d-Urobilin[4] ($C_{33}H_{40}O_6N_4 \cdot 2H_2O$)?	Unknown	2 Yellow	Or.-yel. cryst.; MP = 174°C; HCl = 165°C; s. eth. ac.; sl. s. me. al.	Dioxane-HCl: 495.2 $[\alpha]^{20}_{D}$ HCl: +5000	- - - ? + (+)	Oxidation product of 3 (above) in infected bile and in feces of patients treated with tetracyclines.	A,G,7,12; B,C,F, a;D,E, 12
				Biladienes				
7	Bilirubin ($C_{33}H_{36}O_6N_4$)	M V M P P M M V HO - - - - - - OH H H_2 H - H H -	2 x 2 Orange	MP dimeth. est. = 198-200°C; s. hot pyr., hot chl., CCl_4, dil.	Chloroform: 450(56) NaOH: 420	+ + - + - +	Main product of breakdown of hemoglobin and other heme compounds; in gallstones, bile feces of newborn, hemorrhagic infarcts (hematoidin). "Indirect bilirubin"	A,1,2;B,C, F,G,a; D,1;E,2, 20,21

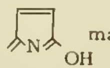
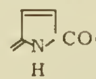
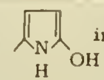
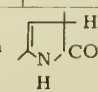
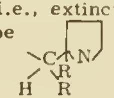
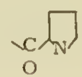
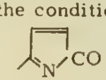
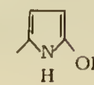
				alk.; sl. s. ac. a., eth. ac.; i. w., al., eth.				in serum of hemolytic jaundice is bilirubin combined with serum albumin. "Direct bilirubin" of bile and in serum and urine of other forms of jaundice is bilirubin diglucuronide, free or combined with serum albumin. Reduction with Na/Hg gives mesobilane. S reaction with iodine: 635 mμ band of bilipurpurin.	
8	Mesobilirubin ($C_{33}H_{40}O_6N_4$)	M E M P P M M E HO - - - - - - OH H H_2 H - H H -	2 x 2 Orange	MP = 315°C, dimeth. est.·HCl = 190°C; s. pyr., chl., dil. alk., sl. s. eth. ac., eth.; i. w.	Chloroform:	425(61.4)	+ + - + - +	Possibly present in small intestine and bile. Reduction with Na/Hg gives mesobilane. S reaction with iodine: 625 mμ band of mesobilipurpurin.	A,1;B-D, F,a;E, 2;G,3
9	Mesobili-erythrin (mesobili-rhodin) ($C_{33}H_{40}O_6N_4$)	M E M P P M M E HO - - - - - - =O H_2 H H_2 H H - - ?	2 or 3 Red	S. chl., bz., dil. alk.; sl. s. eth.; i. w.	HCl/chloroform: 5% HCl: Zn complex in al.:	605(weak) 557(weak) 497 560 495 630(weak) 509	- - - + + + S grn.-yel. fluorescence	Prosthetic group of phycoerythrins (chromoproteins of red and some blue algae) which act as efficient photosynthesizers in algal photosynthesis. Similar pigments in fishes and invertebrates.	A,2,14;B, C,D,F, a;E,2; G,2,4,15
10	Mesobiliviolin ($C_{33}H_{40}O_6N_4$)	M E M P P M M E HO - - - - - - OH H H_2 H - H - H	3 Violet	MP·HCl = 165°C; s. chl., bz., dil. alk.; sl. s. eth.; i. w.	Chloroform: 5% HCl: Zn complex in al.:	570-575 598 625-629 575(weak)	- - - + + + S red fluorescence	Prosthetic group of phycocyanins (chromoproteins of blue and some red algae) which act as efficient photosynthesizers in algal photosynthesis. Similar pigments in fishes and invertebrates. In human feces, probably derived from mesobilane.	A,2,14; B-D,F, a;E,2; G,2,4, 15

/1/ A ring  may be present in the prototropic form , and a ring  in the form . /2/ Abbreviations: ac.a. = acetic acid; acet. = acetone; al. = alcohol; alk. = alkali(ne); am. = amyl; bz. = benzene; chl. = chloroform; cryst. = crystal(line); dil. = dilute; dimeth. = dimethyl; est. = ester; eth. = ether; eth. ac. = ethyl acetate; glac. = glacial; grn. = green; i. = insoluble; MP = melting point; me. = methyl; or. = orange; pet. = petroleum; pyr. = pyridine; sl. = slightly; s. = soluble; w. = water; yel. = yellow. $[\alpha]_D^{20}$ = optical rotation at 20°C. /3/ λ maximum in mμ = wave length of maximum absorption; figures in parentheses are $E_{1\,cm}^{mM}$, i.e., extinction coefficients of millimolar solution of 1 cm thickness. /4/ The nomenclature is misleading. "Stercobilin" and "stercobilinogen," as well as "urobilin" and "urobilinogen," occur in feces and urine. All six compounds (1-6), not only 1 and 4, belong the pigment type IX-α. l-, d-, and i- (inactive) refer to the optical rotations of the bilenes (4-6), but these three compounds are not stereochemical isomers. /5/ According to Watson, C. J., et al [12]. /6/ According to Fischer, H., and Orth, H., [1], and Fischer, H., and Halbach, H., [13].

Part III: BILIRUBINOIDS AND RELATED DIPYRRYL COMPOUNDS (Concluded)

	Substance	Substituents in Positions[1] 1 ¦ 2 ¦ 3 ¦ 4 ¦ 5 ¦ 6 ¦ 7 ¦ 8 1' ¦ 2' ¦ 3' ¦ 4' ¦ 5' ¦ 6' ¦ 7' ¦ 8' α ¦ β ¦ γ ¦ I ¦ II ¦ III ¦ IV	Number of Pyrrole Nuclei in Chromophor, and Color	Other Physical and Chemical Properties[2]	Spectral Characteristics λ maximum in mμ[2,3]	Reactions G¦D¦E¦P¦S¦F	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
				Bilatrienes				
11	Biliverdin (uteroverdin; oocyan) ($C_{33}H_{34}O_6N_4$)	M ¦ V ¦ M ¦ P ¦ P ¦ M ¦ M ¦ V HO ¦ - ¦ - ¦ - ¦ - ¦ - ¦ - ¦ OH H ¦ H ¦ H ¦ - ¦ H ¦ - ¦ -	4 Blue-green	MP dimeth. est. = 216-233°C; s. hot me. al., hot glac. ac. a., dil. alk.; sl. s. eth., chl., dil. HCl; i. w.	Me. al.: 640(10.4) 392(25) 5% HCl/me. al.: 680(28) 377(48) Aqueous HCl/ al.: λ max 675 λ min 500	+ ¦ - ¦ - ¦ + ¦ - ¦ -	Intermediate in bilirubin formation from hemoglobin. In green bile of some animals, meconium, egg shells of many birds, placenta of some mammals, hematomas; also in invertebrates. Blue-green stage of Gmelin reaction. S reaction with iodine same as for bilirubin. Biliverdin-iron present as prosthetic group of (inactive) liver catalase.	A,D,E,2; B,C,F, a;G,2-4, 15,16
12	Glaucobilin (mesobiliverdin) ($C_{33}H_{38}O_6N_4$)	M ¦ E ¦ M ¦ P ¦ P ¦ M ¦ M ¦ E HO ¦ - ¦ - ¦ - ¦ - ¦ - ¦ - ¦ OH H ¦ H ¦ H ¦ - ¦ H ¦ - ¦ -	4 Green-blue	MP = 316-318°C, dimeth. est. = 214-232°C; s. hot me. al., dil. alk.; sl. s. eth., chl., dil. HCl; i. w.	5% HCl/me. al.: 670(30.9) 363(46.8) 309(17.8)	+ ¦ - ¦ - ¦ + ¦ - ¦ -	Glaucobilin or related bilatrienes present in hemolymph and integuments of insects and in other invertebrates. S reaction with iodine same as for mesobilirubin.	A,D,1,2;B, C,F,a; E,2;G,2, 4,15
				Biladienones				
13	Bilichrysin ($C_{33}H_{34}O_7N_4$) and mesobilichrysin	M ¦ V(E) ¦ M ¦ P ¦ P ¦ M ¦ M ¦ V(E) HO ¦ - ¦ - ¦ - ¦ - ¦ - ¦ - ¦ =O H ¦ H_2 ¦ O= ¦ - ¦ H ¦ - ¦ H	2 Yellow	MP mesobilichrysin = 240°C.	Mesobilichrysin in NH_3/al.: 416(40.5) 311(23)	(+) ¦ (+) ¦ - ¦ + ¦ (+) ¦ + S reaction slowly red fluorescence	Isomerization products of some bilipurpurins.	A,2;B-D, F,G,a;E, 1,2
14	Bilipurpurins[7] ($C_{33}H_{34}O_7N_4$) and related compounds	M ¦ V ¦ M ¦ P ¦ P ¦ M ¦ M ¦ V HO ¦ - ¦ - ¦ - ¦ - ¦ - ¦ - ¦ OH H ¦ H ¦ O= ¦ - ¦ H ¦ - ¦ H	3 Purple	Resembles biliviolins.	Zn complex in al.: 635-645 Zn complex of meso compound: 619-630	- ¦ - ¦ - ¦ + ¦ + ¦ - S reaction red fluorescence	Purple stage of Gmelin reaction and other oxidations of bilirubins and biliverdins.	A,2,17;B-G,a
				Bilenediones				
15	Choletelins[7] ($C_{33}H_{34}O_8N_4$) and related compounds	M ¦ V ¦ M ¦ P ¦ P ¦ M ¦ M ¦ V HO ¦ - ¦ - ¦ - ¦ - ¦ - ¦ - ¦ OH O= ¦ H ¦ O= ¦ H ¦ H ¦ - ¦ H	2 Yellow	Resembles urobilins.	HCl/al.: 490-495 Zn complex in al.: 505-515	- ¦ - ¦ - ¦ + ¦ + ¦ - S reaction green fluorescence	Final yellow stage of Gmelin reaction and other oxidations of bilirubins, biliverdins, and bilipurpurins.	A,2;B-G,a

				Dipyrrolic Compounds				
16	Probilifuscins (bilileucanes), bilifuscins, propentdyopents, and pentdyopents ($C_{15-17}H_{18-22}O_{4-6}N_2$)	Structures not definitely established. Dihydroxy-dipyrrylmethanes and their oxidation and polymerization products.	1 or 2 Colorless or brown	Probilifuscins: Amorphous, colorless; s.w.; i.bz., pet. eth.; transformed by acid into brown amorphous bilifuscins.	No characteristic absorption.	- | - | - | - | - | -	Products of oxidative-reductive decomposition of bile pigments and heme compounds. In feces and pathological urines; also obtained from gallstones. Artifacts, but some possibly formed in intestine in vivo.	A,2,4,18, 19;B,C, E,F,a; D,18,19; G,3,4
				Pentdyopents and propentdyopents: Crystalline, colorless; s.w., red Na salts.	Characteristic absorption band in NaOH approximately 525 mμ (523-535 mμ) which accounts for name, "pentdyopent."	- | - | - | + | - | -		

/1/ A ring  may be present in the prototropic form  and a ring  in the form . /2/ Abbreviations: ac.a. = acetic acid; acet. = acetone; al. = alcohol; alk. = alkali(ne); am. = amyl; bz. = benzene; chl. = chloroform; cryst. = crystal(line); dil. = dilute; dimeth. = dimethyl; est. = ester; eth. = ether; eth. ac. = ethyl acetate; glac. = glacial; grn. = green; i. = insoluble; MP = melting point; me. = methyl; or. = orange; pet. = petroleum; pyr. = pyridine; sl. = slightly; s. = soluble; w. = water; yel. = yellow. /3/ λ maximum in mμ = wave length of maximum absorption; figures in parentheses are $E^{mM}_{1\ cm}$, i.e., extinction coefficients of millimolar solution of 1 cm thickness. /7/ According to the conditions of formation the linkage between rings III and IV may be  (R = OH, OCH_3, NO_2, or Br), as well as ; and ring IV may be  as well as 

Contributors: (a) Lemberg, R., (b) Rossi-Fanelli, A., (c) Schmid, R.

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90. PHYSICAL, CHEMICAL, AND BIOLOGICAL PROPERTIES: CYTOCHROMES OF ANIMALS AND HIGHER PLANTS

The cytochromes of animals and higher plants are intracellular chromoproteins which are entirely associated with lipoprotein structural elements of the cytoplasm. The prosthetic group contains coordinated iron which may undergo alternate oxidation and reduction.

	Source	Cytochrome	Physical and Chemical Properties[1]	Spectral Characteristics λ maximum in $m\mu^2$ Reduced	Spectral Characteristics λ maximum in $m\mu^2$ Oxidized	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Animal Pigments						
1	Pigments of mitochondria[3]	a	PG = hematin-a; E'_o = 0.29 volts.	603 452	590-600 418-420		B,C,1,2;B,D,3;B,E,4
2		a_3		604 448	590-600 418-420	Carbon monoxide-a_3 complex, when reduced, has absorption bands at 590-593 mμ and at 432 mμ.	B,D,F,3;E,4;F,5
3		b	PG = protohematin; E'_o = -0.04 volts.	564(20.8) 530 430	416		B-D,6,7;C,2;E,6
4		c	MW = 12,200; PG = hematin-c; Fe = 0.45%; heat stable at neutral pH; isoelectric point pH 10.5-10.8; E'_o = 0.255 volts.	550(27.8) 520 415 316	530 408 355	Data refer to pigment purified from horse heart. Fe content may be increased by enrichment with iron-containing impurities.	B,C,8-11;B,D,E,12,13;F,9,10,12,13
5		c_1	PG = hematin-c.	553-554 522-524 416-418	410	Identical with cytochrome-e.	B,D,14,15;C,E,14;F,15,16
6	Pigments of the endoplasmic reticulum[4]	b_5	MW = 16,900; PG = protohematin; non-mitochondrial oxidation of reduced DPN and of reduced TPN; E'_o = 0.12 volts.	556(25.6) 526 423 320-340	500-580 413 355-370	Identical with cytochrome-m. Separate flavoproteins catalyze the reactions of DPNH and of TPNH with cytochrome-b_5 in animal tissues.	B,D,E,17;C,17,18;F,18,19
7	Intracellular pigments[5]	h	MW = 18,500; PG = modified protohematin; Fe = 0.33%; heat stable at neutral pH; isoelectric point <pH 4.3; E'_o = 0.20 volts.	556(22.7) 526.5 422	562 536 408	Occurs in land snails and other invertebrates. Helicorubin is probably a degraded form of cytochrome-h.	B,C,F,20,21;D-E,20
	Higher Plant Pigments						
8	Pigments of mitochondria[6]	a	As found in animal mitochondria. Presence indicated by spectroscopic and spectrophotometric observations.				A-E,22-25,
9		a_3				Role in electron transport inferred by cyanide inhibition of respiration, and by shift in spectrum observed with carbon monoxide.	A-E,22-25;F,22,24,26
10		b					A-E,22-25
11		c					A-E,22-25,27
12		c_1				Present in high concentration in wheat roots.	A-E,22-25,27;F,22
13		b_7		560 529		Observed in mitochondria from spadix of *Arum maculata*.	B-F,28
14	Pigments of the endoplasmic reticulum[7]	b_3	PG = protohematin; non-mitochondrial oxidation of reduced DPN and of reduced TPN.	559 525 425		Observed in microsomes from wheat roots and beet petiole. A pigment with a similar spectrum observed in autolisates of green leaves.	B,C,25;B,D,22,25;F,22,29
15	Pigments of chloroplasts[8]	b_6	PG = protohematin; E'_o = -0.06 volts.	563		Distinguished from cytochrome-b by greater stability to organic solvents.	B-F,30

16	f	MW = 110,000; PG = hematin-c; heat labile; E'_0 = 0.365 volts.	555 526 421 330	410 350	Isolated from parsley. Localization in chloroplasts observed in etiolated leaves.	B-F,31;F,32

/1/ PG = prosthetic group; MW = molecular weight; E'_0 = oxidation-reduction potential. /2/ λ maximum in mμ = wave length of maximum absorption; figures in parentheses are $E^{mM}_{1\,cm}$, i.e., extinction coefficients of millimolar solutions of 1 cm thickness. /3/ e.g., from rat liver [33]. /4/ Found in microsomes [18, 19]. /5/ Intracellular localization unknown. /6/ e.g., from wheat roots [22]. /7/ Found in microsomes [25]. /8/ Cytochrome-b_6 and cytochrome-f probably are components of a system for oxidation of reduced lipoic acid formed during photosynthesis. The energy from this oxidation is used for generation of ATP from ADP and inorganic phosphate. [34]

Contributors: Morton, R. K., and Armstrong, J. M.

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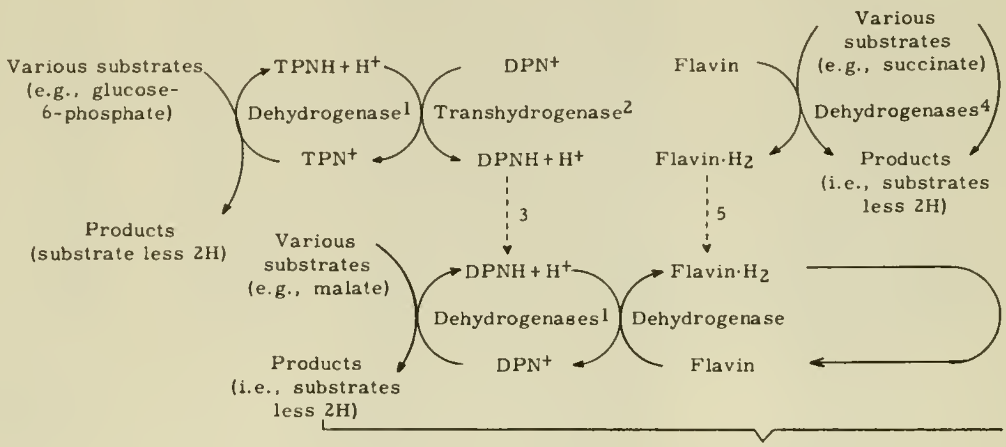
The cytochromes are part of the terminal oxidation system (oxygen reduced by the hydrogen atoms from various reduction. The energy of the various partial oxidations is used to form adenosine triphosphate (ATP) from adenosine process is known as "oxidative phosphorylation." [1-3] The following schematic drawing shows some of the known oxidized.

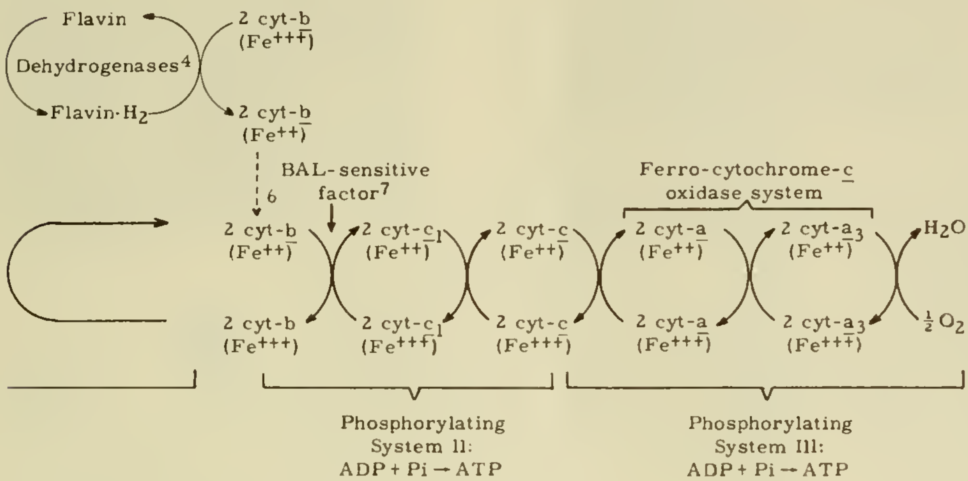


/1/ Some substrates are activated by DPN-specific, some by TPN-specific dehydrogenases. DPN (diphosphopyridine II, respectively. /2/ Transhydrogenase catalyzes transfer of hydrogen from reduced TPN to DPN. /3/ The dotted from the action of a DPN-specific dehydrogenase. /4/ Succinic dehydrogenase, for example, is a typical flavoprotein reduce the flavin prosthetic group of a dehydrogenase directly in the respiratory chain, or /6/ reduce the heme is destroyed by BAL (British Anti-Lewisite, or 1, 2-mercaptopropanol) influences the interaction of cytochrome-b A. [5]

Contributor: Morton, R. K.

References: [1] Chance, B., and Williams, G. R., J. Biol. Chem. 217:429, 1955. [2] Chance, B., Williams
[4] Slater, E. C., Biochem. J., Lond. 45:14, 1949. [5] Potter, V. R., and Reif, A. E., J. Biol. Chem. 194:287,

substrates, thus forming water). Each step, as indicated in the diagram below, involves both oxidation and
diphosphate (ADP) and inorganic phosphate (Pi), by coupling with the various phosphorylating enzyme systems. This
components of the respiratory chain. Up to three molecules of ATP may be synthesized per molecule of DPNH



nucleotide) and TPN (triphosphopyridine nucleotide) are commonly used abbreviations for Coenzyme I and Coenzyme
arrow indicates that reduced DPN arising by transhydrogenase action eventually may pool with reduced DPN formed
dehydrogenase of the respiratory chain. /5/ The dotted arrows indicate that the reduced flavoprotein may either
prosthetic group of cytochrome b, which is part of the respiratory chain. /7/ Slater has shown that a factor which
with cytochrome-c. [4] This may be identical with a factor which is sensitive to low concentrations of Antimycin

G. R., Holmes, W. F., and Higgins, J., ibid 217:439, 1955. [3] Slater, E. C., Chem. wbl., Amst. 53:180, 1957.
1952.

92. PHYSICAL, CHEMICAL, AND BIOLOGICAL PROPERTIES: BACTERIAL CYTOCHROMES

Cytochromes are characterized by their typical bands in the absorption spectra and these can be distinguished in intact bacteria. Some bacteria contain cytochromes with absorption spectra similar to those of cytochromes present in mammalian tissues and yeast. However, the bacterial cytochromes may not be identical with the mammalian pigments, even though they serve similar functions. Other bacteria have cytochromes with rather different absorption spectra. In the bacteria studied, except the anaerobic and photosynthetic, all of the cytochromes are rapidly oxidized in air and reduced when the oxygen in solution is exhausted.

Part I: ABSORPTION SPECTRA OF CYTOCHROMES IN INTACT BACTERIA

Cytochromes $\underline{a}_1$, $\underline{a}_2$, $\underline{a}_4$, $\underline{b}_1$, $\underline{b}_4$, $\underline{c}_2$, $\underline{c}_3$, $\underline{c}_4$, and $\underline{c}_5$ have been observed to occur only in bacteria.

	Cytochrome (A)	Sources (B)	Spectral Characteristics[1] λ maximum in mμ[2] (C)			Function (D)
1	a	Micrococcus pyogenes var. albus, Bacillus subtilis, Sarcina lutea	605	None	?	Intermediate in electron transport.
2	a_1	Acetobacter pasteurianum, Azotobacter vinelandii, Proteus vulgaris	590	?	440[3]	Terminal oxidase.
3	a_2	Escherichia coli, Proteus vulgaris, Aerobacter aerogenes	635	?	?	Alternate terminal oxidase.[4]
4	a_3	Bacillus subtilis, Sarcina lutea	605	None	445	Terminal oxidase.
5	a_4	Acetobacter peroxidans	612	?	?	Unknown.
6	b	Bacillus subtilis, Sarcina lutea, Micrococcus pyogenes var. albus	563	535	430	Intermediate in electron transport.
7	b_1	Escherichia coli, Proteus vulgaris, Aerobacter aerogenes	560	?	430[3]	Intermediate in electron transport.
8	b_4	Halotolerant bacteria	554	521	418	
9	c	Micrococcus denitrificans, Pseudomonas aeruginosa, P. denitrificans	550	520	415	Intermediate in electron transport.
10	c_1	Acetobacter pasteurianum, A. suboxydans, Bacillus subtilis	554	523	419	Intermediate in electron transport.
11	c_2	Rhodospirillum rubrum, Rhodopseudomonas spheroides	550	520	415	Not part of respiratory chain; may be involved in light-induced reactions.
12	c_3	Desulfovibrio desulfuricans	553	525	419	Electron carrier during reduction of sulfate and related ions.
13	c_4	Azotobacter vinelandii	551	522	416	Intermediate in electron transport.
14	c_5	Azotobacter vinelandii	555	526	420	Intermediate in electron transport.

/1/ For reduced form. /2/ Wave length of maximum absorption. /3/ Approximately. /4/ Varies with growth phase of cells.

Contributor: Smith, L.

References: [1] Keilin, D., C. rend. Soc. biol. 97:Appendix 39, 1927. [2] Smith, L., Bact. Rev., Balt. 18:106, 1954. [3] Keilin, D., and Hartree, E. F., Nature, Lond. 164:254, 1949. [4] Chance, B., J. Biol. Chem. 202:383, 1953. [5] Kamen, M. D., Bact. Rev., Balt. 19:250, 1955.

Part II: PROPERTIES OF SOLUBLE BACTERIAL CYTOCHROMES

The cytochromes listed below have been isolated from bacteria in soluble form and purified to varying degrees.

	Cytochrome[1] (A)	Source (B)	Physical and Chemical Properties[2] (C)	Spectral Characteristics[3] λ maximum in mμ[4] (D)	Remarks (E)	Reference (F)
1	b_4	Halotolerant bacteria		554 521 518	Appears to be a "c-type" cytochrome; the preparation is probably a mixture of at least two pigments.	1
2	c	Pseudomonas aeruginosa	Not auto-oxidizable; hemin like cytochrome-c; Fe = 0.45%; IP at acid pH; E'_0 = 0.30 volts.	550-552 521-525 416-418	Intermediate electron carrier in reduction of nitrate and O_2.	2-4
3		Micrococcus denitrificans	Not auto-oxidizable; hemin like cytochrome-c; IP at acid pH; E'_0 = 0.25 volts.		Intermediate electron carrier in reduction of nitrate and O_2; can be oxidized by pig heart cytochrome-c oxidase.	
4		Pseudomonas denitrificans	Not auto-oxidizable; hemin like cytochrome-c; E'_0 = 0.32 volts.		Intermediate electron carrier in reduction of nitrate and O_2.	
5	c_2	Rhodospirillum rubrum	MW = 13,000; same hemin as cytochrome-c; not absorbed on ammonium form of Amberlite IRC-50; IP less than that of cytochrome-c; E'_0 = 0.34 volts.	550 520 415	Not a part of respiratory chain of R. rubrum [7]; not oxidized by mammalian cytochrome-c oxidase. May be involved in reactions following illumination.	5, 6

6		Rhodospirillum spheroides			Not oxidized by mammalian cytochrome-c oxidase. May be involved in reactions following illumination.	
7	c3	Desulfovibrio desulfuricans	MW = 13,000; same hemin as cytochrome-c; no reaction with CO or cyanide; auto-oxidizable; appears to have two hemin groups per molecule; rather stable to heat and acid; Fe = 0.92%; IP between pH 10.30-10.66; E'_0 = -0.204 volts.	553 525 419	Electron carrier during reduction of sulfate and related ions.	8,9
8	c4	Azotobacter vinelandii	MW = 12,000; same hemin as cytochrome-c; relatively stable to heat and alkali; denatured in acid; not auto-oxidizable; does not combine with CO or cyanide; Fe = 0.46%; IP at acid pH; E'_0 = 0.32 volts.	551(23.8) 522(17.6) 416(157.2)	Part of the bacterial respiratory chain. Not oxidized by oxidases of heart muscle, Escherichia coli, or Acetobacter peroxidans.	10
9	c5	Azotobacter vinelandii	Not auto-oxidizable; same hemin as cytochrome-c; relatively stable to heat and alkali; denatured in acid; does not combine with CO or cyanide; IP at acid pH; E'_0 = 0.30 volts.	555 526 420	Part of the bacterial respiratory chain. Not oxidized by oxidases of heart muscle, Escherichia coli, or Acetobacter peroxidans.	10
10	Chromatium cytochrome	Chromatium sp	MW = 30,000-38,000; hemin like cytochrome-c; appreciably auto-oxidizable; E'_0 = -0.04 volts	552 525 418	Preparation is probably a mixture of two pigments.	11
11	Chlorobium cytochromes	Chlorobium thiosulfatophilum	Two pigments isolated, having protein parts of different basicity; one is absorbed on Amberlite IRC-50, other is not.	554 523 417		12,13
			Pigment 1: Fe = 0.37%; slowly auto-oxidizable, but does not combine with CO; E'_0 = 0.16 volts.			
12		Chlorobium limicola		553 520 415	Impure mixture.	
13	Pseudomonas fluorescens cytochrome	Pseudomonas fluorescens		550 520 415	Contains a peroxidase which oxidizes the cytochrome in presence of H_2O_2. Not reduced by liver TPNH-cytochrome-c reductase.	14

/1/ Bacterial cytochrome-c is not identical with that of mammalian tissues. /2/ IP = isoelectric point; MW = approximate molecular weight; E'_0 = oxidation-reduction potential at pH 7. /3/ For reduced pigment. /4/ λ maximum in mμ = wave length of maximum absorption; figures in parentheses are $E^{mM}_{1\,cm}$, i.e., extinction coefficients of millimolar solutions of 1 cm thickness.

Contributor: Smith, L.

References: [1] Egami, F., Itahashi, M., Sato, R., and Mori, T., J. Biochem., Japan 40:527, 1953. [2] Verhoeven, W., and Takeda, Y., in "Symposium on Nitrogen Metabolism," p159, Baltimore: Johns Hopkins Univ. Press, 1956. [3] Kamen, M. D., and Vernon, L. P., Biochim. biophys. acta 17:10, 1955. [4] Kamen, M. D., and Takeda, Y., ibid 21:518, 1956. [5] Elsden, S. R., Kamen, M. D., and Vernon, L. P., J. Am. Chem. Soc. 75:6347, 1953. [6] Vernon, L. P., and Kamen, M. D., J. Biol. Chem. 211:643, 1954. [7] Smith, L., in "Symposium on Photosynthesis," p313, New York: Interscience Publishers, 1957. [8] Postgate, J. R., J. Gen. Microb., Lond. 14:545, 1956. [9] Ishimoto, M., and Koyama, J., Bull. Chem. Soc., Japan 28:231, 1955. [10] Tissières, A., Biochem. J., Lond. 64:582, 1956. [11] Newton, J. W., and Kamen, M. D., Biochem. biophys. acta 21:71, 1956. [12] Kamen, M. D., and Vernon, L. P., J. Bact., Balt. 67:617, 1954. [13] Gibson, J., and Larsen, H., Biochem. J., Lond. 60:xxvii, 1955. [14] Lenhoff, H. M., and Kaplan, N. O., J. Biol. Chem. 220:967, 1956.

93. MAXIMAL BREATHING CAPACITY: CHILDREN AND ADOLESCENTS

Maximal breathing capacities, of seated subjects, were measured in a Benedict-Roth type spirometer (Collins ventilometer) with the soda lime container and valves removed. MBC values have been corrected to BTPS conditions (cf Page 1); those in parentheses are ranges and conform to estimate "b" of the 95% range (cf Introduction).

Part I: VS AGE

	Age yr	Males		Females	
		no.	MBC, L/min	no.	MBC, L/min
	(A)	(B)	(C)	(D)	(E)
1	5.0-5.9	4	42(30-54)	12	41(19-63)
2	6.0-6.9	8	45(25-65)	8	53(42-63)
3	7.0-7.9	6	65(53-77)	18	53(33-73)
4	8.0-8.9	7	69(49-89)	19	60(36-85)
5	9.0-9.9	7	73(35-111)	29	67(46-88)
6	10.0-10.9	10	79(43-115)	22	72(49-94)
7	11.0-11.9	6	75(61-89)	28	79(49-109)
8	12.0-12.9	3	109(75-143)	28	96(47-144)
9	13.0-13.9	20	117(67-167)	14	104(67-141)
10	14.0-14.9	72	117(68-166)	19	99(39-160)
11	15.0-15.9	9	129(61-197)	12	105(59-152)
12	16.0-16.9	5	134(108-160)	10	92(56-128)
13	17.0-17.9	4	155(133-177)	12	108(59-157)
14	18.0-18.9			2	123(83-163)

Contributors: (a) Ferris, B. G., Jr., (b) Whittenberger, J. L.

References: [1] Males: Ferris, B. G., Jr., Whittenberger, J. L., and Gallagher, J. R., Pediatrics, Springf. 9:659, 1952. [2] Females: Ferris, B. G., Jr., and Smith, C. W., ibid 12:341, 1953.

Part II: VS STANDING HEIGHT

Subjects measured in stocking feet.

	Height cm	Males		Females	
		no.	MBC, L/min	no.	MBC, L/min
	(A)	(B)	(C)	(D)	(E)
1	100.0-109.9			4	41(14-69)
2	110.0-119.9	7	44(30-58)	13	47(28-71)
3	120.0-124.9	5	45(21-69)	10	62(29-94)
4	125.0-129.9	4	63(45-81)	15	58(38-77)
5	130.0-134.9	5	69(33-105)	19	62(41-83)
6	135.0-139.9	9	68(30-106)	30	72(50-94)
7	140.0-144.9	9	79(63-95)	19	74(47-100)
8	145.0-149.9	9	82(58-106)	12	78(41-115)
9	150.0-154.9	5	86(48-124)	23	90(48-132)
10	155.0-159.9	12	102(72-132)	38	95(52-137)
11	160.0-164.9	13	115(61-169)	18	103(50-155)
12	165.0-169.9	30	113(66-160)	17	107(51-164)
13	170.0-174.9	29	127(75-179)	6	124(95-153)
14	175.0-179.9	16	129(107-151)		
15	180.0-184.9	8	148(110-186)		

Contributors: (a) Ferris, B. G., Jr., (b) Whittenberger, J. L.

References: [1] Males: Ferris, B. G., Jr., Whittenberger, J. L., and Gallagher, J. R., Pediatrics, Springf. 9:659, 1952. [2] Females: Ferris, B. G., Jr., and Smith, C. W., ibid 12:341, 1953.

Maximal breathing capacities, of seated subjects, were measured in a Benedict-Roth type spirometer (Collins ventilometer) with the soda lime container and valves removed. MBC values have been corrected to BTPS conditions (cf Page 1); those in parentheses are ranges and conform to estimate "b" of the 95% range (cf Introduction).

Part III: VS WEIGHT

Subjects weighed without heavy clothing.

	Weight kg	Males		Females	
		no.	MBC, L/min	no.	MBC, L/min
	(A)	(B)	(C)	(D)	(E)
1	15.0-19.9			6	36(24-48)
2	20.0-24.9	9	46(28-64)	26	53(33-73)
3	25.0-29.9	7	53(21-85)	17	61(41-81)
4	30.0-34.9	12	74(40-108)	29	65(38-92)
5	35.0-39.9	11	71(39-103)	28	78(51-104)
6	40.0-44.9	10	83(61-105)	28	77(43-112)
7	45.0-49.9	15	93(73-113)	24	88(48-127)
8	50.0-54.9	8	110(52-168)	25	98(40-155)
9	55.0-59.9	22	121(85-157)	26	100(45-155)
10	60.0-64.9	29	129(75-183)	15	106(59-153)
11	65.0-69.9	12	119(65-173)	4	98(51-145)
12	70.0-74.9	12	126(62-190)	3	126(91-161)
13	75.0-79.9	11	122(74-170)	1	132
14	80.0-84.9	3	136(104-168)		

Contributors: (a) Ferris, B. G., Jr., (b) Whittenberger, J. L.

References: [1] Males: Ferris, B. G., Jr., Whittenberger, J. L., and Gallagher, J. R., Pediatrics, Springf. 9:659, 1952. [2] Females: Ferris, B. G., Jr., and Smith, C. W., ibid 12:341, 1953.

Part IV: VS SURFACE AREA

Surface area obtained from DuBois nomogram.

	Surface Area sq m	Males		Females	
		no.	MBC, L/min	no.	MBC, L/min
	(A)	(B)	(C)	(D)	(E)
1	0.60-0.79			9	42(21-63)
2	0.70-0.89	8	46(28-64)		
3	0.80-0.89			18	53(30-76)
4	0.90-0.99	5	48(16-80)	14	60(24-95)
5	1.00-1.09	9	65(35-95)	25	63(39-88)
6	1.10-1.19	9	70(32-108)	30	70(48-92)
7	1.20-1.29	10	79(55-103)	23	76(49-102)
8	1.30-1.39	10	84(62-106)	22	81(43-119)
9	1.40-1.49	11	93(79-107)	24	91(47-135)
10	1.50-1.59	12	108(52-164)	32	93(44-142)
11	1.60-1.69	22	110(70-150)	24	107(54-160)
12	1.70-1.79	36	130(85-175)	9	121(85-156)
13	1.80-1.89	12	130(70-190)	3	130(96-164)
14	1.90-1.99	14	125(73-177)		
15	2.00-2.09	3	148(124-172)		

Contributors: (a) Ferris, B. G., Jr., (b) Whittenberger, J. L.

References: [1] Males: Ferris, B. G., Jr., Whittenberger, J. L., and Gallagher, J. R., Pediatrics, Springf. 9:659, 1952. [2] Females: Ferris, B. G., Jr., and Smith, C. W., ibid 12:341, 1953.

94. MAXIMAL BREATHING CAPACITY: MAN

Ventilatory values have generally been corrected to BTPS conditions (cf Page 1). Values in parentheses are ranges and conform to estimate "c" of the 95% range (cf Introduction). Ventilatory data of Shock conform to estimate "b."

	Age yr (A)	Height cm (B)	Weight kg (C)	Surface Area sq m (D)	MBC L/min (E)	Author (F)	Reference (G)
				Males			
1	8.1	124.8	21.4	0.87	37	Morse	1
2	9.5	148.2	41.6	1.31	62		
3	11.5(11.3-11.7)	154.2(146.0-162.5)	42.7(37.3-48.0)	1.37(1.25-1.49)	55(46-63)		
4	12.5	153.3	39.9	1.31	91		
5	13.4	171.7	58.7	1.69	129		
6	14.0	169.5	51.7	1.56	94		
7	19.3	172.2	61.6	1.72	144		
8	23	165.9	65.4	1.77	172		
9	24.3	167.1	62.6	1.71	218		
10	30.0	182.3	68.0	1.89	155		
11	35.6	174.2	54.2	1.62	106		
12	24.5(20-29)	174.3(164.7-183.9)	77.5(39.1-115.9)	1.92(1.53-2.31)	126(55-198)	Shock	2
13	34.5(30-39)	176.6(166.2-187.0)	74.2(52.4-96.0)	1.90(1.65-2.15)	114(55-173)		
14	44.5(40-49)	173.2(162.8-183.6)	67.8(45.3-90.3)	1.81(1.57-2.05)	101(40-162)		
15	54.5(50-59)	171.3(158.4-184.2)	63.0(46.2-79.8)	1.74(1.49-1.99)	74(21-126)		
16	64.5(60-69)	167.8(158.6-177.0)	63.5(44.9-82.1)	1.72(1.48-1.96)	67(14-120)		
17	74.5(70-79)	166.9(154.9-178.9)	63.2(36.7-89.7)	1.71(1.36-2.06)	54(14-93)		
18	83.1(80-87)	163.9(147.8-180.0)	59.7(39.9-79.5)	1.65(1.34-1.96)	48(4-92)		
19	20.9(15.8-25.9)				168(124-212)	Gray	3
20	23.3(16.5-30.1)	179.1(167.9-190.3)	71.7(54.5-88.9)		169(130-207)	Matheson	4
21	23.5(18.0-29.0)				145(76-214)	Malamos	5
22	23.5(21.0-26.0)				166(125-207)	Dripps	6
23	24.1	178.8	72.7		169(126-208)	Gray	3
24	25.5(13.5-37.5)	173.8(156.6-191.0)	66.0(49.4-82.6)		126(69-183)	Baldwin	7
25	42.7(34.5-50.9)	171.7(157.9-185.5)	64.9(42.5-87.3)	1.76	109(78-141)		
26	58.1(43.1-73.1)	168.5(151.1-185.9)	63.0(38.8-87.2)	1.72	103(62-144)	Galdston	8
27	59.6(48.8-70.4)	169.6(153.0-186.2)	63.3(49.1-83.5)	1.72	91(57-124)	Baldwin	7
				Females			
28	6.3(6.2-6.4)	122(121-123)	23.3(23.0-23.6)	0.94(0.90-0.98)	45(35-54)	Morse	1
29	7.7(7.6-7.9)	128(128-129)	28.3(25.0-31.6)	1.00(0.95-1.05)	42(35-50)		
30	8.3(8.1-8.6)	132(127-137)	30.8(27.9-33.8)	1.07(1.05-1.08)	38(34-42)		
31	9.5(9.0-9.9)	140(140-142)	33.8(26.0-42.9)	1.15(1.03-1.27)	48(41-52)		
32	10.3(10.1-10.6)	145(144-147)	35.5(29.6-40.4)	1.21(1.11-1.29)	67(49-92)		
33	11.5(11.1-11.8)	151(148-153)	38.0(27.7-46.7)	1.27(1.06-1.44)	63(47-81)		
34	12.6(12.2-12.9)	158(141-172)	47.1(36.0-54.0)	1.48(1.26-1.69)	75(43-96)		
35	13.4(13.2-13.7)	159(148-165)	53.8(43.0-59.0)	1.54(1.40-1.60)	103(57-150)		
36	14.5(14.2-14.9)	165(162-169)	53.7(53.1-54.3)	1.58(1.57-1.60)	127(87-194)		
37	15.4(15.2-15.6)	165(160-170)	60.5(53.2-74.4)	1.66(1.54-1.85)	110(89-141)		
38	18.4(18.0-18.8)	168(158-177)	57.5(42.4-65.5)	1.65(1.39-1.82)	120(107-143)		
39	20.2(20.0-20.4)	165(161-168)	56.0(47.2-64.9)	1.63(1.50-1.76)	129(122-137)		
40	21.5(21.3-21.7)	159(149-164)	51.8(43.0-59.5)	1.51(1.34-1.63)	110(97-127)		
41	22.2(22.0-22.4)	166(157-174)	64.9(56.3-73.6)	1.72(1.56-1.88)	162(144-180)		
42	23.4(23.0-23.9)	167(157-175)	65.8(51.1-88.4)	1.74(1.50-1.98)	132(81-209)		
43	24.4(24.3-24.7)	165.1(158.4-169.3)	59.9(47.6-70.4)	1.64(1.53-1.81)	129(93-181)		
44	25.4(25.0-25.8)	163.7(159.5-167.9)	59.9(59.4-60.4)	1.66(1.64-1.68)	109(108-110)		
45	26.1	165.5	55.1	1.63	118		
46	28.7(28.5-28.9)	172(171-173)	59.6(56.0-63.1)	1.74(1.71-1.76)	126(109-144)		
47	29.1	170.2	45.6	1.50	101		
48	30.0	175.6	79.5	1.96	184		
49	34.0	152.2	57.0	1.53	145		
50	36.5(36.5-36.6)	161(155-166)	52.8(50.2-55.3)	1.54(1.47-1.61)	98(82-113)		
51	24.3(12.6-36.0)	164.9(151.0-178.8)	56.2(44.0-68.4)		116(74-158)	Gray	3
52	25.1(12.7-37.5)	161.8(149.4-174.2)	59.2(37.0-81.4)		94(69-119)	Baldwin	7
53	27.2(17.2-37.1)	160.0(128.8-191.2)	60.3(42.7-77.9)	1.62	100(67-134)	Cournand	9
54	43.3(36.1-50.5)	164.0(150.4-177.6)	62.6(32.0-93.2)	1.67	89(53-125)	Baldwin	7
55	44.8(23.6-66.0)	163.6(152.8-174.4)	59.9(44.9-74.9)	1.64	86(55-118)	Galdston	8
56	59.8(41.8-77.8)	158.4(145.0-171.8)	67.2(45.2-89.2)	1.67	73(40-107)	Baldwin	7

Contributors: (a) Galdston, M., (b) Morrow, P. E., (c) Morse, M., (d) Shock, N. W.

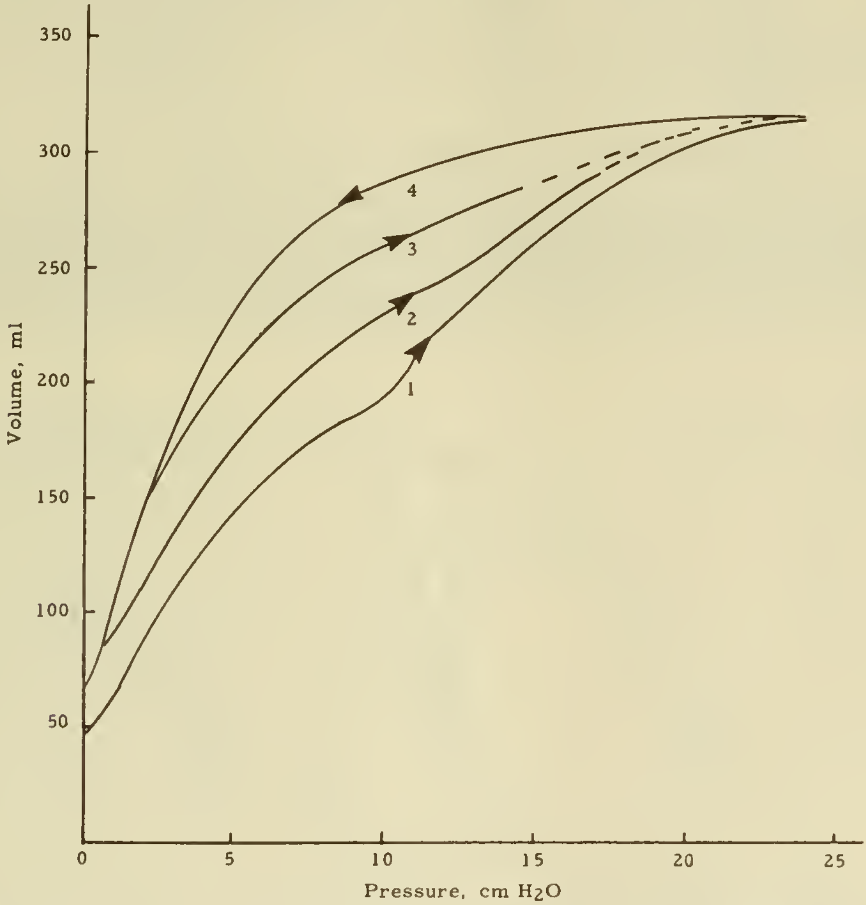
References: [1] Morse, M., Univ. of Chicago, unpublished. [2] Shock, N. W., Norris, A. H., Landowne, M., and Falzone, J. A., Jr., J. Geront. 11:379, 1956. [3] Gray, J. S., Barnum, D. C., Matheson, H. W., and Spies, S. N., J. Clin. Invest. 29:677, 1950. [4] Matheson, H. W., and Gray, J. S., ibid 29:688, 1950. [5] Malamos, B., Beitr. Klin. Tuberk. 93:225, 1938. [6] Dripps, B. D., and Comroe, J. H., Jr., Am. J. Physiol. 149:43, 1947. [7] Baldwin, E. de F., Cournand, A., Richards, D. W., Jr., Medicine 27:243, 1948. [8] Galdston, M., Wolfe, W. B., and Steele, J. M., J. Appl. Physiol. 5:17, 1952. [9] Cournand, A., Richards, D. W., Jr., and Darling, R. C., Am. Rev. Tuberc. 40:487, 1939.

Although a large literature has accumulated on the mechanics of breathing, comparison of results often is difficult because of differences in experimental technique. Measurements of lung compliance may yield different results when the elastic pressure changes are measured during spontaneous or rapid breathing, as against those measured under true static conditions when air flow is stopped for a second or more. An additional complication in measurements of compliance arises because the pressures observed during slow volume changes depend on the previous degree of expansion of the lungs. (Part 1 illustrates slow pressure-volume changes in the cat; similar lung behavior has been observed for other mammals, including man.) Thus lung compliance determinations depend on whether measurements are made (1) from the normal resting volume, (2) after a deep inspiration, or (3) with the functional residual capacity decreased, either voluntarily or involuntarily, from effects of posture or anesthetics. Most of the measurements given in the tables below have been made from the resting lung volume, usually in sitting individuals. The reservations cited above apply also to measurements of lung resistance; furthermore, the measured resistance may depend on the lung volume, as well as on the frequency of breathing.

Contributor: Radford, E. P., Jr.

Part 1: SLOW PRESSURE-VOLUME CURVES: CAT

Cat, weighing 3.7 kilograms, lungs exposed, lay in tank respirator; lung volume changes were produced by slowly decreasing tank pressure. Three different inflation curves were obtained after the lungs had been allowed to deflate to various pressures. Each inflation or deflation curve required 20-30 seconds.



/1/ Lungs allowed to collapse completely and immediately reinflated slowly. /2/ Lungs deflated to a pressure of 0.6 cm H_2O after a maximum inflation, then reinflated. /3/ Lungs deflated to 2 cm H_2O and immediately reinflated. /4/ Deflation (following procedures used in obtaining Curve 1), shown for comparison.

Contributor: Radford, E. P., Jr.

Reference: Radford, E. P., Jr., "Tissue Elasticity," p 186, Baltimore: American Physiological Society, 1957.

Part II: INTRAPULMONARY PRESSURES AT VARIOUS LUNG VOLUMES: MAN

All measurements made on males in sitting position. Mean lung volumes are per cent of vital capacity at ambient pressure. Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Maximum Expiratory Pressure			Maximum Inspiratory Pressure			Relaxation Pressure[1]			
	Subjects no.	Volume %	Positive Pressure mm Hg	Subjects no.	Volume %	Negative Pressure mm Hg	Subjects no.	Volume %	Pressure mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	12	9.7	41.5(14.7-68.3)	11	3.9	86.0(47.0-125.0)	14	0	-19.2(-31.8 to -6.6)	1
2	12	25.0	52.5(10.9-94.1)	11	21.7	74.6(46.4-102.8)	14	13.9	-8.5(-15.5 to -1.5)	1
3	12	43.8	69.9(30.5-109.3)	11	34.8	63.3(25.9-100.7)	14	31.0	-1.3(-9.9 to 7.3)	1
4	12	60.0	90.0(47.0-133.0)	11	55.6	56.8(25.6-88.0)	14	51.0	4.1(-1.9 to 10.1)	1
5	12	75.0	93.3(58.1-128.5)	11	75.7	44.8(16.8-72.8)	14	72.0	10.5(1.9-19.1)	1
6	12	83.0	107.0(74.4-139.6)	11	91.0	23.6(2.2-49.4)	14	87.0	14.9(0.3-29.5)	1
7	100	100.0	119.0(86.0-145.0)				14	100.0	20.6(10.2-31.0)	1, 2

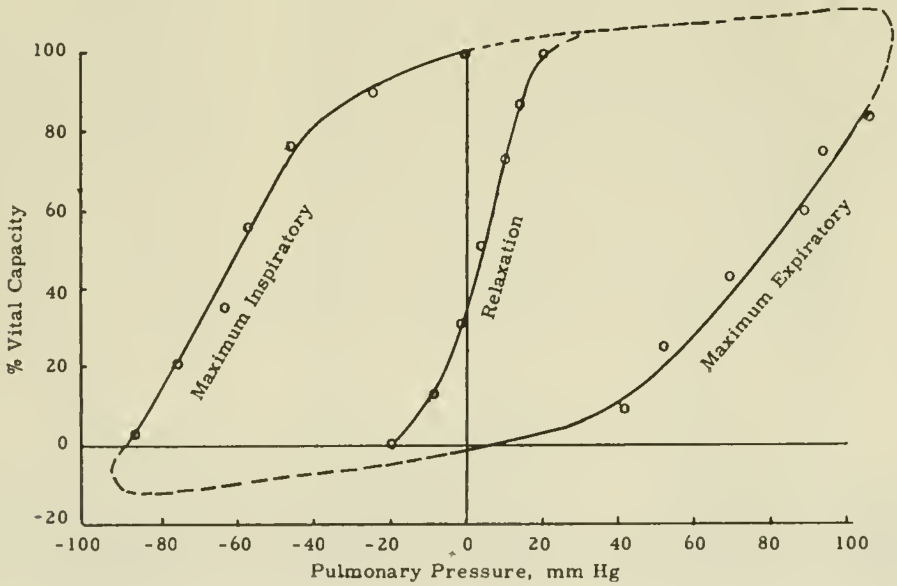
/1/ Measured with glottis open at desired lung volume; one nostril plugged and other connected with a water manometer.

Contributors: (a) Lees, W. M., Snider, G. L., and Fox, R. T., (b) Radford, E. P., Jr., (3) Dayman, H. G.

References: [1] Rahn, H., Otis, A. B., Chadwick, L. E., and Fenn, W. O., Am. J. Physiol. 146:161, 1946. [2] Gross, D., Am. Heart J. 25:335, 1943.

Part III: PRESSURE-VOLUME DIAGRAM OF CHEST AND LUNGS: MAN

On the ordinates 100% of vital capacity represents the height of inspiration, and 0% of vital capacity represents maximum expiration, both at zero pressure or ambient pressure in the lungs. The diagram shows the pressures which can be developed passively (relaxation pressure) or actively (maximum pressures) at different lung volumes. In the upper right corner where the lung is maximally expanded and the pressure has a positive value, there is danger of rupture of the lung (broken line in diagram). In the lower left corner where the blood vessels are exposed to a maximum negative pressure, there is extreme vasodilation and danger of hemorrhage (broken line in diagram).



Contributors: (a) Fenn, W. O., (b) Radford, E. P., Jr.

References: [1] Fenn, W. O., in "Handbook of Respiratory Physiology" (Boothby, W. M., ed), Randolph Field, Texas: USAF School of Aviation Medicine, 1954. [2] Fenn, W. O., Rivista Di Medicina Aeronautica, 1955.

Part IV: INTRAPLEURAL PRESSURES: MAN

Values expressed as gauge pressures (cm of H_2O less than ambient atmospheric pressure).

	No. and Sex	Inspiration	Expiration	Reference
	(A)	(B)	(C)	(D)
1	20♂	-7.3(-14.0 to -4.0)	-3.8(-10.0 to -2.0)	1
2	40♂, 10♀	-9.3(-14.6 to -3.9)[1]	-3.8(-8.7 to -1.1)[1]	2

/1/ Measurements made with a modified Lillingston and Pearson pneumothorax apparatus.

Contributors: (a) Lees, W. M., Snider, G. L., and Fox, R. T., (b) Radford, E. P., Jr.

References: [1] Lees, A. W., Glasgow M. J. 32:1, 1951. [2] Laha, P. N., Ind. M. Gazette 81:359, 1946.

Part V: COMPLIANCE OF LUNG-THORAX SYSTEM: MAMMALS

	Animal	Condition	Weight kg	Compliance L/cm H2O	Reference
	(A)	(B)	(C)	(D)	(E)
1	Man	Unanesthetized, supine		0.12	1-3
2		Anesthetized, supine	66	0.062	1-3
3	Cat	Anesthetized	3.2	0.0068	4
4		Anesthetized	2.6	0.0057	4-6
5	Dog	Anesthetized	20	0.048	5, 7
6		Anesthetized	11.8	0.0265	5, 8
7	Rabbit	Anesthetized	2	0.0023	9

Contributors: (a) DuBois, A. B., (b) Ross, B. B., (c) Radford, E. P., Jr., (d) Frank, N. R.

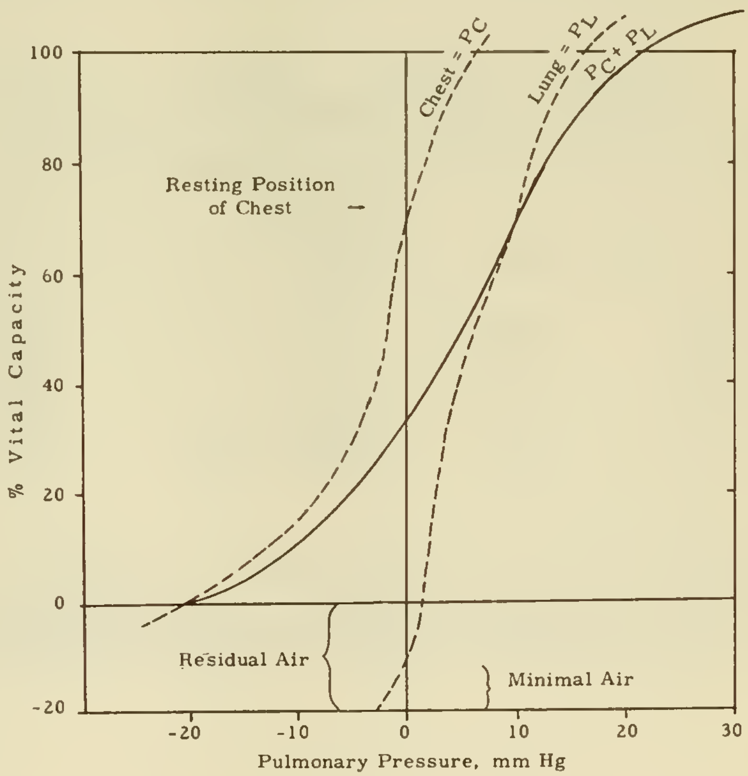
References: [1] Nims, R. G. Conner, E. H., and Comroe, J. H., Jr., J. Clin. Invest. 34:744, 1955. [2] Rahn, H., Otis, A. B., Chadwick, L. E., and Fenn, W. O., Am. J. Physiol. 146:161, 1946. [3] Otis, A. B., Fenn, W. O., and Rahn, H., J. Appl. Physiol. 2:592, 1950. [4] Nisell, O. I., and DuBois, A. B., Am. J. Physiol. 178:206, 1954. [5] Brody, A. W., ibid 178:189, 1954. [6] Brody, A. W., DuBois, A. B., Nisell, O. I., and Engelberg, J., ibid 186:142, 1956. [7] Van Liew, H. D., ibid 177:161, 1954. [8] Severinghaus, J. W., and Stupfel, M., J. Appl. Physiol. 8:81, 1955. [9] Bernstein, L., J. Physiol. 123:44P, 1954.

Part VI: RELAXATION PRESSURE CURVE: MAN

The relaxation pressure curve (solid line) of the chest and lungs ($P_C + P_L$) consists of two components (broken lines), the elasticity of the chest and diaphragm (P_C) and the elasticity of the lungs (P_L). At the normal relaxation volume, where the relaxation pressure curve crosses the axis, the elasticity of the lung is exactly balanced by the elasticity of the chest, and both are equal in magnitude to the intrapleural pressure, or 4 mm Hg at expiration. The lung curve intersects the relaxation pressure curve at a volume of about 70% of the vital capacity, at which point the chest curve crosses the axis and all of the relaxation pressure is due to the elasticity of the lung. The lung curve presumably intersects the "0" axis in the residual air region at a point that measures the minimal air.

Contributors: (a) Fenn, W. O., (b) Radford, E. P., Jr.

Reference: Fenn, W. O., in "Handbook of Respiratory Physiology" (Boothby, W. M., ed), Randolph Field, Texas: USAF School of Aviation Medicine, 1954.



Part VII: PULMONARY COMPLIANCE: MAN

Two standard methods of measuring pulmonary compliance give similar results in normal subjects. Static Method: The intra-esophageal pressure upon interruption of air flow after an inspiration of 0.5 and 1.0 L, is subtracted from the intra-esophageal pressure upon interruption of air flow at the end expiratory level. Compliance is expressed as L/cm H_2O pressure difference. Dynamic Method: The intra-esophageal pressure at the instant of zero air flow after inspiration, is subtracted from the intra-esophageal pressure at the instant of zero air flow after expiration. This pressure difference during normal breathing is divided into the tidal volume of that breath. The value is usually expressed as an average for 5 or 10 breaths. Capacity values are for ATPS. Values in parentheses are ranges and are estimate "c" of the 95% range (cf Introduction), unless otherwise indicated.

	Condition	Method	Age	No. and Sex	Functional Residual Capacity, L	Vital Capacity L	Compliance[1] L/cm H_2O	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Supine	Dynamic	1 hr-7 da	18♂ and ♀			0.005(0.002-0.009)	1
2	Sitting	Dynamic	28(19-49)	49♂		5.02(2.20-7.80)	0.19(0.14-0.33)	2-4
3		Dynamic	22(19-29)	11♀		3.14(2.30-3.80)	0.13(0.09-0.18)	2, 3, 5
4		Static	28(21-43)	60♂		4.70(3.30-5.90)	0.20(0.14-0.31)	4-7
5		Static	26(18-43)	42♀		3.57(3.00-4.20)	0.14(0.09-0.22)	4-6, 8
6		Static	69(50-87)	8♂, 18♀		3.09(1.79-4.39)[b]	0.13(0.058-0.202)[b]	9
7	During Exercise[2]	Dynamic	24(20-36)	29♂	3.84(2.5-6.5)		0.22(0.13-0.39)	2
8		Dynamic	21(19-29)	7♀	2.37(1.7-3.2)		0.13(0.09-0.18)	2, 3, 5

/1/ Intra-esophageal pressure taken as equivalent to intrathoracic pressure in determining pressure differential across the lung. /2/ Treadmill speed, 3 miles per hour.

Contributors: (a) McIlroy, M. B., (b) Alexander, J. K., (c) Fritts, H. W., (d) Frank, N. R., (e) Radford, E. P., Jr., (f) Turino, G. M.

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Part VIII: PULMONARY COMPLIANCE VS VITAL CAPACITY: MAN

Measurements made using the intra-esophageal balloon technique on young adults, 18-35 years old, in sitting position. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	No. and Sex	Vital Capacity L	Compliance L/cm H_2O	Reference
	(A)	(B)	(C)	(D)
1	9♀	2.5-3.0	0.13(0.10-0.18)	1-3
2	13♀	3.0-3.5	0.15(0.09-0.22)	1, 4, 5
3	18♀	3.5-4.0	0.15(0.10-0.25)	1, 2, 4-6
4	7♂	3.5-4.0	0.17(0.11-0.25)	1, 3
5	13♂	4.0-4.5	0.18(0.09-0.28)	1-3, 7
6	20♂	4.5-5.0	0.20(0.15-0.33)	1-4, 6, 7
7	14♂	5.0-5.5	0.22(0.15-0.32)	1, 4, 6
8	7♂	Over 5.5	0.27(0.24-0.33)	1, 4, 6, 7

Contributor: Ebert, R. V.

References: [1] Frank, N. R., Mead. J., Siebens, A. A., and Storey, C. F., J. Appl. Physiol. 9:38, 1956. [2] Attinger, E. O., Monroe, R. G., and Segal, M. S., J. Clin. Invest. 35:905, 1956. [3] Heaf, P. J., and Prime, F. J., Clin. Sc., Lond. 15:319, 1956. [4] Mead, J., and Whittenberger, J. L., J. Appl. Physiol. 5:779, 1953. [5] Brown, C. C., Fry, D. L., and Ebert, R. V., Am. J. M. 17:438, 1954. [6] Cherniack, R. M., J. Clin. Invest. 35:394, 1956. [7] Stead, W. W., Fry, D. L., and Ebert, R. V., J. Laborat. Clin. M. 40:674, 1952.

Part IX: PULMONARY COMPLIANCE: VERTEBRATES

	Animal	Weight kg	Compliance L/cm H_2O	Reference
	(A)	(B)	(C)	(D)
1	Man, infant, 1 wk old	3	0.0052	1
2	Man, adult	70	0.2	2
3	Cat	2	0.006	3
4	Dog	20	0.09	4
5	Frog		0.001	5
6	Guinea pig		0.0008	6
7	Horse	430	0.8	7
8	Rat	0.225	0.0012	8

Contributors: (a) DuBois, A. B., (b) Ross, B. B., (c) Radford, E. P., Jr.

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Part X: CLINICAL RANGE OF PULMONARY COMPLIANCE: MAN

Adult male of average size (ht = 180 cm).

	Condition	Degree of Alteration	Compliance L/cm H_2O
	(A)	(B)	(C)
1	No pulmonary restriction	Normal	0.19(0.12-0.26)
2	Pneumonectomy, pulmonary congestion, bronchospasm	Slight	0.09(0.06-0.12)
3	Asthma, repeated heart failure, poliomyelitis, kyphoscoliosis, pulmonary infiltration (sarcoidosis, scleroderma)	Moderate	0.05(0.03-0.06)
4	Pulmonary fibrosis, pulmonary carcinomatosis	Severe	0.02(0.01-0.03)

Contributors: (a) DuBois, A. B., (b) Radford, E. P., Jr.

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Part XI: RESISTANCE OF LUNGS AND AIRWAY: MAN

Resistive pressure determined from esophageal pressure measurements. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Subjects	Rate of Air Flow L/sec	Resistive Pressure cm H_2O	Resistance cm H_2O/L/sec	Reference
	(A)	(B)	(C)	(D)	(E)
1	18 infants, newborn	0.05	1.0	29	1
2	8 adults, male	0.5	0.85(0.55-1.20)[1]	1.70	2
3		1.0	1.81(1.10-2.55)[1]	1.81	2
4		1.5	2.87(1.75-4.25)[1]	1.91	2
5	1 adult, male (asthmatic)	0.5	17.7[1]	35.4	2

/1/ Measured during inspiration only.

Contributor: Radford, E. P., Jr.

References: [1] Cook, C. D., Sutherland, J. M., Segal, S., Cherry, R. B., Mead, J., McIlroy, M. B., and Smith, C. A., J. Clin. Invest. 36:440, 1957. [2] McIlroy, M. B., Mead, J., Selverstone, N. J., and Radford, E. P., Jr., J. Appl. Physiol. 7:485, 1955.

96. MEAN RESPIRATORY AIR FLOW CHARACTERISTICS: MAN

Subjects at rest. Volumes were measured at ATPS conditions (cf Page 1). Summary values are averages of means.

	Specifications	Phase Duration[1]		Flow Rate[2]		Maximum Flow Rate[2]		Flow Acceleration[3]		Flow Deceleration[4]		Reference
		Inspiration sec	Expiration sec	Inspiration L/sec	Expiration L/sec	Inspiration L/sec	Expiration L/sec	Inspiration L/sec/sec	Expiration L/sec/sec	Inspiration L/sec/sec	Expiration L/sec/sec	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
1	Children, ♂♀	1.00	1.40	0.35	0.32	0.46	0.43					1
2	Adults, ♂	1.99	2.28	0.328	0.282	0.480	0.440					2
3		1.43	1.62			0.717	0.808	1.87	1.75	1.64	1.10	3
4		1.78	2.02			0.673	0.400	1.72	1.50	1.42	0.76	4
5						0.417	0.383					5
6		1.20	1.44	0.436	0.354	0.606	0.393					1
7	Average	1.60	1.84	0.382	0.318	0.579	0.485	1.79	1.63	1.53	0.93	
8	Adults, ♀	1.63	1.89	0.335	0.265	0.513	0.463					2
9		1.10	1.41	0.405	0.321	0.567	0.585					1
10	Average	1.37	1.65	0.370	0.293	0.540	0.524					
11	Adults, ♂♀	2.31	3.13			0.71	0.65					6
12				0.38	0.28	0.58	0.48	2.0	1.2			7
13		1.45	1.56	0.344	0.262	0.508	0.415					8
14		1.62	2.09	0.310	0.242	0.427	0.379					9
15	Average	1.79	2.26	0.34	0.26	0.56	0.48					

/1/ Period of measurable air flow. /2/ Tidal air flow. /3/ Average air flow increase during phase initiation. /4/ Average air flow decrease during phase termination.

Contributors: (a) Morrow, P. E., (b) Scott, C. C.

References: [1] Hartwich, A., Zschr. ges. exp. Med. 69:482, 1929-30. [2] Bretschger, H. J., Pflügers Arch. 210:134, 1952. [3] Specht, H., Marshall, L. H., and Hoffmaster, B., Am. J. Physiol. 157:265, 1949. [4] Specht, H., Marshall, L. H., and Spicknall, B. H., J. Appl. Physiol. 2:363, 1950. [5] Silverman, L., Lee, R. C., and Drinker, C. K., J. Clin. Invest. 23:907, 1944. [6] Cain, C. C., and Otis, A. B., J. Aviat. M. 21:149, 1949. [7] Proctor, D. F., and Hardy, J., Bull. Johns Hopkins Hosp. 85:253, 1949. [8] Rumpf, K., Zschr. ges. exp. Med. 101:493, 1937. [9] Fleisch, A., Pflügers Arch. 214:595, 1926.

97. RESPIRATORY REFLEXES: MAN

Reflexes, except where noted, have been demonstrated in man. Many respiratory alterations exist for which receptors or reflex routes are not known, and all reflexes depend upon net prevailing integrated activity of countless other reflexes. CAC = cardio-accelerator center, CIC = cardio-inhibitor center, VCC = vasoconstrictor center, RC = respiratory centers in brain stem.

	Reflex	Stimulus	Conditions Initiating Stimulus	Reflex Pathway				Predominant Response	Reference
				Receptor Cell	Afferent Nerve	Center	Efferent Nerve		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Respiratory								
1	Propriocepto-respiratory	Motion of extremities.		Stretch (?) receptors in joints (and tendons ?).	Somatics.	RC stimulated.	Phrenics, thoracics.	Increased respiratory rate[1] or depth[2].	1
2	Vena cavo-respiratory (Harrison)	Blood pressure in great veins, right atrium.		Stretch receptors in great veins, right atrium.	Vagus.	RC stimulated.		Hyperpnea.	1
3	Alveolo-respiratory (Hering-Breuer)	Moderate inflation of lungs.		Slowly adapting alveolar stretch receptors.		RC depressed.		Apnea.	1
4	Alveolo-respiratory (acceleratory)	Extreme inflation or deflation.		Rapidly adapting alveolar stretch receptors.	Vagus.	RC stimulated.		Increased respiratory rate without important circulatory effects[3].	1
5	Bronchiolo-respiratory (cough reflex)	Irritation of the bronchiolar mucosa.	Inhalation of irritant gases and vapors; respiratory infections.	Free nerve endings (?).	Vagus.	RC stimulated.		Expiratory blast or cough.	1
	Mixed Respiratory and Cardiovascular								
6	Coronary reflex	Occlusion of coronary artery.	Thrombotic, embolic, or atherosclerotic occlusion.	Visceral pain receptors (?).	Cardiac sympathetics.	CAC[4], VCC; RC stimulated.	Vagus, sympathetics, phrenics, thoracics.	Vasoconstriction, tachycardia[4], polypnea.	1
7	Pulmonary vein reflex	Pressure increase in pulmonary vessels.		Stretch receptors in pulmonary veins.	Pulmonary vagus.	VCC; RC stimulated.	Sympathetics, phrenics, thoracics.	Vasodilatation, apnea followed by polypnea (diphasic).	1
8	Aortic body and carotid body reflex	Arterial blood O_2 decrease; blood free CO_2 increase; pH decrease.	Acetylcholine, acidosis, anemia, asphyxia, deep anesthesia.	Chemoreceptors in aortic, carotid bodies.	Glossopharyngeal (Hering's); vagus (Cyon's).	CAC, VCC; RC stimulated.	Vagus, sympathetics, phrenics, thoracics.	Heart rate increased, vasoconstriction, hyperpnea, generalized convulsions.	2-5

/1/ In dog. /2/ In cat. /3/ In dog and rabbit. /4/ Usual result of coronary occlusion is tachycardia, but in some cases there is a complicating vaso-vagal reflex which results in bradycardia and fall in blood pressure.

Contributors: (a) Peel, A. A. F., (b) Aviado, D. M., Jr., (c) Grayson, J., (d) Nahum, L. H., (e) Peterson, L. H.

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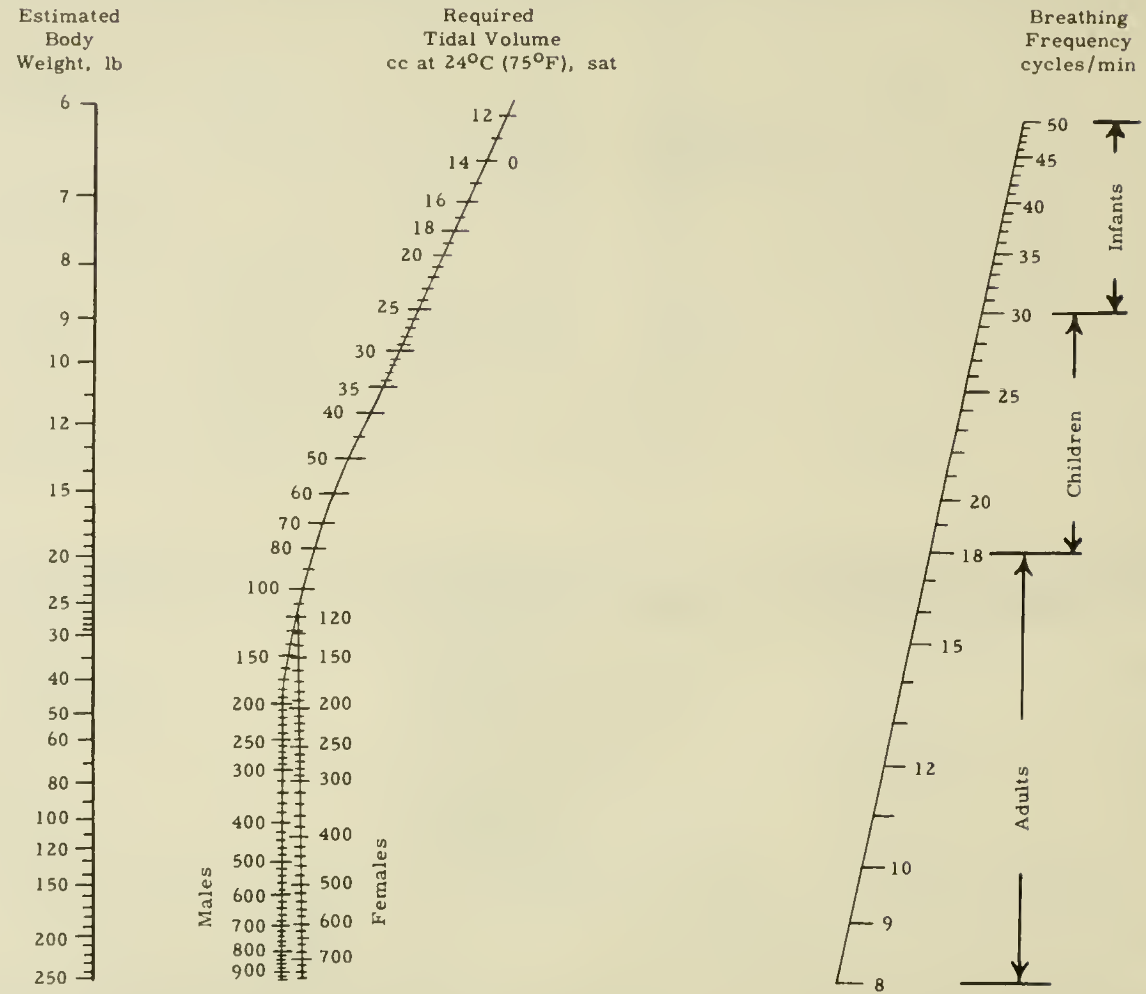
98. REQUIRED TIDAL VOLUME VS BODY WEIGHT AND BREATHING FREQUENCY: MAN

Ventilation nomogram to be used in estimating adequacy of tank respirator settings. Correction factors to be applied to tidal volumes obtained from nomogram: daily activity and eating, add 10%; fever, add 5% for each °F above 99 degrees, rectal; altitude, add 5% for each 2000 ft above sea level; tracheotomy, after all above corrections have been added, subtract volume equal to one-half body weight. sat = saturated with water vapor.



Contributor: Abajian, J., Jr.

Reference: Radford, E. P., Jr., J. Appl. Physiol. 7:451, 1955.

99. MEAN TIDAL VOLUME FOR VARIOUS TECHNIQUES OF ARTIFICIAL RESPIRATION: MAN

Part I: APNEIC INFANTS

Values are cubic centimeters air per respiratory cycle for five infants with endotracheal intubation.

	Age mo	Weight lb	Tidal Volume, cc								
			Sleeping	Mouth-to-Mouth	Chest-pressure Arm-lift	Back-pressure Arm-lift[1]	Back-pressure Hip-lift[2]	Manual Rocking			
								Prone		Supine	
								45°-45°	30°-60°	45°-45°	30°-60°
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
1	5	15	32	94	46	41	58	18	20	22	25
2	12	22	48	150	98	62	106	24	28	30	36
3	24	31	62	220	110	86	116	35	42	45	50
4	30	30	87	248	124	111	133	42	46	52	62
5	36	38	94	284	206	184	210	65	72	86	92

/1/ Arm-lift alone gave values of 30-50% of back-pressure arm-lift. /2/ Hip-lift alone gave values of 35-45% of back-pressure hip-lift.

Contributor: Gordon, A. S.

Reference: Gordon, A. S., and Frye, C. W., J. Am. M. Ass. (in press).

Part II: APNEIC ADULTS

Apnea induction: A-C = anesthesia and curare; D-A = drug and anesthesia; I-P = intracranial pathology. Airway: N = natural, no artificial airway used; A = artificial oropharyngeal (standard Connell airway that prevents lip obstruction and reaches to base of tongue); E = cuffed endotracheal tube. Head position: N = no support of head or mandible; E = neck extended at atlanto-occipital joint. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	No. and Sex	Age yr	Wt lb	Apnea Induction	Airway	Head Position	Tidal Volume, ml								Reference
							Prone Pressure (Schafer)	Hip-lift (Emerson)	Chest-pressure Arm-lift (Silvester)	Back-pressure Arm-lift (Holger Nielsen)	Back-pressure Hip-roll (Emerson)	Back-pressure Hip-lift (Schafer-Emerson-Ivy)	Eve Rocking		
													Prone	Supine	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)
1	26♂	21-34		A-C	E		485	635[1]	1069[2]	1056	967	1140			1
2	7♂	21-28		A-C	E[3]				1123	1170		1249	574	393	2
3	3♂, 1♀	35-81		I-P			155		285	245	350	405			3
4	8♀	31-59		D-A[4]						474		864			3
5	2♂, 4♀	20-83		I-P			365	352		577		680			4
6	1♂, 4♀		101-174	A-C	E	N or E			503(400-700)	655(260-840)					5-7
7	8♂, 4♀		101-210	A-C	N	N			73(0-560)						5-7
8	10♂, 5♀		101-210	A-C	N	N				126(0-780)					5-7
9	7♂, 1♀		155-210	A-C	N	E			352(0-1060)						5-7
10	6♂		155-180	A-C	N	E				52(0-1160)					5-7
11	8♂, 2♀		165-210	A-C	A	E			418(0-1200)						5-7
12	5♂, 1♀		155-210	A-C	A	E				338(0-760)					5-7
13	6♂, 2♀		155-186	A-C	A	N			84(0-500)						5-7
14	7♂		155-210	A-C	A	N				177(0-840)					5-7
15	Arterial oxygen saturation, %[5]				86(74-95)[6]		67(42-91)			93(89-100)	95(90-100)	88(70-98)	93(89-100)		8

/1/ Ten subjects. /2/ Fifteen subjects. /3/ Wearing full-face gas mask. /4/ During immediate preoperative period. /5/ Measurements made at end of 15-minute periods of artificial respiration on 11 anesthetized and curarized adult males. /6/ Control.

Contributors: (a) Gordon, A. S., (b) Safar, P., (c) Elam, J. O.

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100. VENTILATORY CHARACTERISTICS OF VARIOUS RESPIRATORS AND TECHNIQUES OF ARTIFICIAL RESPIRATION: MAN

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Technique or Respirator	Subjects No.	Subjects Condition and Sex	Subjects Wt, lb	Pressure Applied[1] mm Hg	Tidal Volume ml	Ventilatory Rate per min	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Automatic Mechanical Respirators								
1	Intermittent positive airway pressure	5	Anesthetized and curarized, males and females. Oropharyngeal airway.	108-157	3.9[2]	1127(420-1990)	12	Circulatory effects deleterious, proportional to mean mask pressure.	1-4
2	Cyclic positive airway pressure	12		126-192	4.3[2]	320(70-576)	23		
3	Positive-negative airway pressure (Venturi)	11		108-192	4.1[2]	1139(306-1880)	11		
4	Tank	14	Poliomyelitis patients with nearly complete paralysis, males and females.		-7.4[3]	332	17	Circulatory effects deleterious, proportional to mean (negative) tank pressure (approximately ½ peak pressure). Some subjects inadequately ventilated by cuirass.	5, 6
5					-11.1[3]	519			
6	Cuirass (chest-abdominal)	13			-7.4[3]	214			
7					-11.1[3]	311			
8					-14.8[3]	404			
	Electrophrenic Respirator								
9	Electrophrenic respirator	1			0	865	20	Circulatory effects beneficial.	2, 6
	Manual Artificial Respiration								
10	Chest-pressure arm-lift (Silvester)	10	Anesthetized and curarized, males. Endotracheal airway.	130-205	+ to ++	1146(659-1795)	12	Circulatory effects of maneuvers not interpretable because of blood gas abnormalities. Ventilation may be inadequate without airway or in obese persons.	7-11
11	Back-pressure arm-lift (Nielsen)				++	1101(807-1707)			
12	Hip-roll, prone pressure				+++	1054(671-1564)			
13	Eve rocking					751(511-880)			
14	Hip-lift (Emerson)				+++	635(445-853)			
15	Prone pressure (Schafer)				+	501(342-652)			
16	Back-pressure arm-lift (Nielsen)	15	Anesthetized and curarized, males and females. Natural airway.	101-210	++	126(0-780)		Method taught nation-wide since 1951.	12-14
	Expired Air Inflation								
17	Mouth-to-mouth	15	Anesthetized and curarized, males and females.	110-210	4.0[2]	1500(1000-2000)[4]	6-30	Superiority claimed to methods of manual artificial respiration.	12-15
18	Airway-to-mouth								

/1/ Lines 10-16 indicate effort of operator. /2/ Mean pressure at mask. /3/ Peak pressure at tank. /4/ Approximate.

Contributors: (a) Price, H. L., and Conner, E. H., (b) Safar, P.

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Data from subjects clinically free of pulmonary or cardiovascular disease and in basal conditions. Values for males and females calculated separately. STPS conditions.[1] Ranges in parentheses conform to estimate "b" of the 95% range (cf Introduction).

	Variable	Males		
		Group I: Age 16-34 yr	Group II: Age 35-49 yr	Group III: Age 52-69 yr
	(A)	(B)	(C)	(D)
	Physical characteristics			
1	Age, yr	25.5(mean)	42.7(mean)	59.6(mean)
2	Height, cm	173.8(156.6-191.0)	171.7(157.8-185.6)	169.6(153-186.2)
3	Weight, kg	66.0(49.4-82.6)	64.9(42.5-87.3)	66.3(49.1-83.5)
4	Body surface area, sq m	1.77(1.29-2.05)	1.80(1.48-2.12)	1.80(1.50-2.70)
5	Vital capacity, supine, cc[1]	4012(2780-5244)	4160(3200-5120)	3417(1767-5067)
6	Maximal breathing capacity, standing, L/min[1]	126.0(67.8-183.2)	109.4(77.6-141.2)	90.6(57.0-124.2)
	Ventilation, L/min/sq m BSA[2]			
7	Basal	3.6(3.0-4.2)	3.1(2.1-4.1)	3.9(3.0-4.8)
8	1 min standard exercise[3]	11.0(6.4-15.6)	10.0(5.4-14.6)	11.2(5.8-16.6)
9	1st min recovery	12.5(8.3-16.7)	13.4(8.2-18.6)	14.5(9.5-19.5)
10	2nd min recovery	8.6(5.6-11.6)	9.4(5.2-11.2)	10.8(6.8-14.8)
11	5th min recovery	5.2(3.94-6.46)	5.2(3.8-6.6)	6.3(2.9-8.7)
	Oxygen consumption, cc/min/sq m, BSA			
12	Basal	146(118-174)	131(111-151)	132(98-166)
13	1 min standard exercise	503(331-675)	481(301-661)	506(326-686)
14	5th min recovery	1488(1144-1832)	1493(1301-1665)	1511(1183-1839)
	Oxygen removal, cc/L ventil.			
15	Basal[4]	47.1(37.1-57.1)	46.1(35.1-57.1)	38.5(33.7-43.3)
16	1 min standard exercise	56.2(41.4-71.0)	55.7(42.3-69.1)	55.7(42.3-69.1)

	Variable	Females		
		Group I: Age 16-34 yr	Group II: Age 35-49 yr	Group III: Age 50-79 yr
	(A)	(E)	(F)	(G)
	Physical characteristics			
1	Age, yr	25.1(mean)	43.3(mean)	59.8(mean)
2	Height, cm	161.8(149.4-174.2)	164.0(150.4-177.6)	158.4(145.0-171.8)
3	Weight, kg	59.2(37.0-81.4)	62.6(32.0-93.2)	67.2(45.2-89.2)
4	Body surface area, sq m	1.58(1.30-1.86)	1.72(1.38-2.06)	1.7(1.46-1.94)
5	Vital capacity, supine, cc[1]	3057(1955-4159)	2830(2036-3624)	2431(1367-3495)
6	Maximal breathing capacity, standing, L/min[1]	93.7(68.5-118.9)	89.3(53.5-125.2)	73.5(39.9-107.1)
	Ventilation, L/min/sq m BSA[2]			
7	Basal	3.2(2.4-4.0)	3.2(2.4-4.0)	3.4(2.6-4.2)
8	1 min standard exercise[3]	9.0(5.6-12.4)	11.4(7.8-15.0)	11.4(8.0-14.8)
9	1st min recovery	10.9(7.9-13.9)	11.9(8.5-15.3)	12.6(8.2-17.0)
10	2nd min recovery	8.1(5.5-10.7)	9.2(5.8-12.6)	8.5(6.7-10.3)
11	5th min recovery	4.9(3.7-6.1)	5.2(3.2-7.2)	4.5(2.3-6.7)
	Oxygen consumption, cc/min/sq m, BSA			
12	Basal	126(106-146)	126(108-144)	126(107-151)
13	1 min standard exercise	463(311-615)	505(323-690)	512(370-654)
14	5th min recovery	1318(1158-1478)	1368(1184-1552)	1348(1078-1618)
	Oxygen removal, cc/L ventil.			
15	Basal[4]	45.1(36.5-53.7)	46.0(35.2-58.8)	44.5(36.7-52.3)
16	1 min standard exercise	60.2(41.2-79.2)	53.6(38.8-68.4)	53.5(40.7-66.3)

/1/ Lung volumes and maximal breathing capacity determined by spirographic method. Lung volumes, method of Christie [2], modified by Hurtado and Baller [3]. For lung volumes, resting pulmonary mid-position is point of reference from which all measurements are taken (position of return end quite expiration). The volume of air contained then in the chest is the sum of the reserve and residual airs [2-8]. Maximal breathing capacity apparatus, modified recording spirometer of closed-circuit type derived from Benedict-Roth, calculations at 37° C. [9] /2/ Apparatus: tissot gasometer, electrically driven kymograph; Douglas bag interposed through three-way valve into inflow circuit to spirometer; inspiratory flutter valves connected through tube and mouth piece to patient. CO_2, O_2 determinations by Haldane apparatus. /3/ Step up on platform, 20 cm high, and down again at rate of 30 cycles/min. /4/ Rate of O_2 removal calculated as difference between inspired and expired air O_2 concentrations.

Contributor: (a) Cohn, J. E., (b) Harden, K. A.

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102. EFFECTS OF EXERCISE ON PULMONARY FUNCTION AND HEART RATE: MAN

Values in parentheses are estimate "c" of the 95% range (cf Introduction).

Part I: MALES, 4-33 YEARS

Values obtained over a six-minute period during maximal work on a treadmill or bicycle ergometer.

	Variable	4-6 yr (10 Subjects)	7-9 yr (12 Subjects)	10-11 yr (13 Subjects)	12-13 yr (19 Subjects)	14-15 yr (10 Subjects)	16-18 yr (9 Subjects)	20-33 yr (42 Subjects)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Body height, cm	113.5 (107-128)	135.0 (125-143)	145.4 (132-157)	154.4 (139-169)	171.8 (150-188)	176.9 (165-187)	176.7 (165-188)
2	Body weight, kg	20.8 (16.0-27.8)	30.7 (25.1-36.5)	36.5 (31.1-44.7)	43.6 (31.8-60.6)	59.5 (40.6-76.2)	64.1 (45.2-73.4)	70.4 (61.7-86.6)
3	Vital capacity, BTPS, L		2.21 (1.84-2.51)	2.65 (2.24-3.25)	3.22 (2.52-4.33)	4.55 (2.78-6.57)	5.17 (3.20-6.48)	5.68 (4.17-7.26)
4	Max. heart rate, beats/min	203 (188-214)	208 (191-220)	211 (200-227)	205 (175-237)	203 (178-222)	202 (194-220)	194 (171-212)
5	Max. O_2 uptake, STPD, L/min	1.01 (0.77-1.30)	1.75 (1.40-2.01)	2.04 (1.78-2.32)	2.46 (1.79-3.40)	3.53 (2.59-4.47)	3.68 (2.48-4.35)	4.11 (3.30-5.09)
6	Max. O_2 uptake, STPD, ml/min/kg	49.1 (43.2-57.6)	56.9 (51.8-62.7)	56.1 (51.1-61.5)	56.5 (53.0-61.9)	59.5 (54.8-63.7)	57.6 (51.0-62.4)	58.6 (51.1-67.4)
7	Max. pulmonary ventilation, BTPS, L/min	39.8 (30.9-43.5)	61.8 (44.1-75.2)	70.5 (50.0-77.5)	75.2 (58.1-105.0)	112.9 (84.5-140.3)	110.3 (79.6-139.3)	111.3 (91.5-160.3)
8	Max. respiratory rate, breaths/min	70.4 (63-90)	67.0 (55-83)	57.5 (32-77)	54.1 (31-68)	52.9 (39-68)	44.7 (28-60)	39.9 (27-59)
9	Max. tidal volume, L	0.60 (0.43-0.87)	1.05 (0.72-1.25)	1.33 (1.12-1.62)	1.59 (1.02-2.54)	2.52 (1.62-3.26)	2.77 (1.68-3.40)	3.05 (2.26-4.72)
10	Max. blood lactic acid, mg %	56.3 (33-76)	82.0 (60-110)	84.0 (50-125)	79.1 (45-143)	90.4 (74-113)	104.9 (83-138)	112.0 (71-158)
11	O_2 uptake, $\frac{\text{maximal}}{\text{basal}}$	6.8	9.4	10.2	10.9	13.1	13.5	15.7

Contributor: Åstrand, P.-O.

Reference: Astrand, P.-O., "Experimental Studies of Physical Working Capacity in Relation to Sex and Age," Copenhagen: Ejnar Munksgaard, 1952.

Part II: MALES, 20-66 YEARS

Values obtained over a five-minute period during maximal work on a treadmill.

	Variable	20-29 yr (11 Subjects)	31-38 yr (11 Subjects)	40-48 yr (10 Subjects)	48-55 yr (8 Subjects)	59-66 yr (7 Subjects)
	(A)	(B)	(C)	(D)	(E)	(F)
1	Body height, cm	180	175	177	172	173
2	Body weight, kg	72.9	77.5	75.6	68.6	68.9
3	Vital capacity, BTPS, L	5.25(4.20-6.03)	4.76(3.83-6.49)	4.28(3.76-5.16)	4.16(3.60-5.52)	4.05(3.45-5.04)
4	Max. heart rate, beats/min	193(186-197)	187(176-206)	178(166-184)	174(161-185)	165(154-176)
5	Max. O_2 uptake, STPD, L/min	3.53(2.56-4.50)	3.42(2.76-3.97)	2.92(2.30-3.62)	2.63(2.24-3.35)	2.35(1.64-3.15)
6	Max. O_2 uptake, STPD, ml/min/kg	48.7(41.9-55.6)	43.1(37.6-52.8)	39.5(33.7-46.5)	38.4(33.7-43.2)	34.5(30.2-41.7)
7	Max. pulmonary ventilation, BTPS, L/min	118.2(104-135)	122.4(103-147)	97.6(72-133)	86.8(57-114)	80.8(62-106)
8	Max. respiratory rate, breaths/min	43(32-56)	43(32-48)	39(28-48)	38(28-58)	35(26-44)
9	Residual air, BTPS, L	1.66(0.84-2.94)	1.60(1.27-2.12)	1.48(0.66-2.24)	1.81(1.00-2.38)	1.72(1.43-2.39)
10	Max. blood lactic acid, mg %	89(60-121)	97(70-129)	85(67-114)	73(59-91)	58(46-70)

Contributor: Asmussen, E.

Reference: Robinson, S., Arbeitsphysiologie 10:251, 1938.

Values in parentheses are estimate "c" of the 95% range (cf Introduction).

Part III: FEMALES, 4-25 YEARS

Values obtained over a six-minute period during maximal work on a treadmill or bicycle ergometer.

	Variable	4-6 yr (7 Subjects)	7-9 yr (14 Subjects)	10-11 yr (13 Subjects)	12-13 yr (13 Subjects)	14-15 yr (11 Subjects)	16-17 yr (10 Subjects)	20-25 yr (44 Subjects)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Body height, cm	111.6 (108-114)	132.0 (121-142)	140.6 (129-148)	158.5 (150-175)	164.9 (156-173)	167.7 (162-176)	165.8 (155-175)
2	Body weight, kg	18.4 (17.4-21.9)	27.2 (20.6-33.0)	32.5 (27.0-37.4)	46.7 (39.6-60.5)	56.0 (46.2-67.1)	57.3 (50.5-63.7)	60.3 (50.0-72.8)
3	Vital capacity, BTPS, L		1.95 (1.69-2.24)	2.30 (1.88-2.63)	3.25 (2.52-4.01)	3.74 (2.94-4.32)	4.14 (3.24-5.04)	4.28 (3.15-5.76)
4	Max. heart rate, beats/min	204 (176-214)	211 (194-233)	209 (192-220)	207 (188-222)	202 (192-217)	206 (188-214)	198 (184-225)
5	Max. O_2 uptake, STPD, L/min	0.88 (0.74-0.94)	1.50 (1.21-1.79)	1.70 (1.48-1.94)	2.31 (2.01-2.72)	2.58 (2.02-3.31)	2.71 (2.25-3.08)	2.90 (2.41-3.40)
6	Max. O_2 uptake, STPD, ml/min/kg	47.9 (42.4-52.2)	55.1 (49.3-58.8)	52.4 (46.4-56.1)	49.8 (45.0-53.5)	46.0 (42.5-52.5)	47.2 (42.8-51.2)	48.4 (43.2-59.6)
7	Max. pulmonary ventilation, BTPS, L/min	33.9 (31.0-38.9)	57.3 (48.2-67.6)	61.1 (46.2-80.9)	79.9 (65.5-102.6)	87.9 (68.4-100.7)	93.8 (73.6-119.1)	89.8 (74.4-114.8)
8	Max. respiratory rate, breaths/min	66.4 (56-81)	67.1 (54-94)	61.3 (51-82)	54.4 (41-88)	51.6 (40-58)	51.2 (44-60)	46.0 (28-63)
9	Max. tidal volume, L	0.52 (0.40-0.58)	0.91 (0.64-1.22)	1.05 (0.85-1.36)	1.64 (1.28-2.54)	1.87 (1.34-2.41)	1.95 (1.43-2.28)	2.10 (1.64-3.29)
10	Max. blood lactic acid, mg %	60 (51-69)	76.5 (64-85)	82.2 (56-116)	97.6 (76-119)	100.5 (73-145)	110.2 (77-144)	103.6 (69-134)
11	O_2 uptake, $\frac{\text{maximal}}{\text{basal}}$	6.6	9.1	9.6	10.8	11.6	12.6	14.0

Contributor: Åstrand, P.-O.

Reference: Åstrand, P.-O., "Experimental Studies of Physical Working Capacity in Relation to Sex and Age," Copenhagen: Ejnar Munksgaard, 1952.

103. EFFECT OF VARIOUS WORK LOADS ON PULMONARY FUNCTION AND HEART RATE: MAN

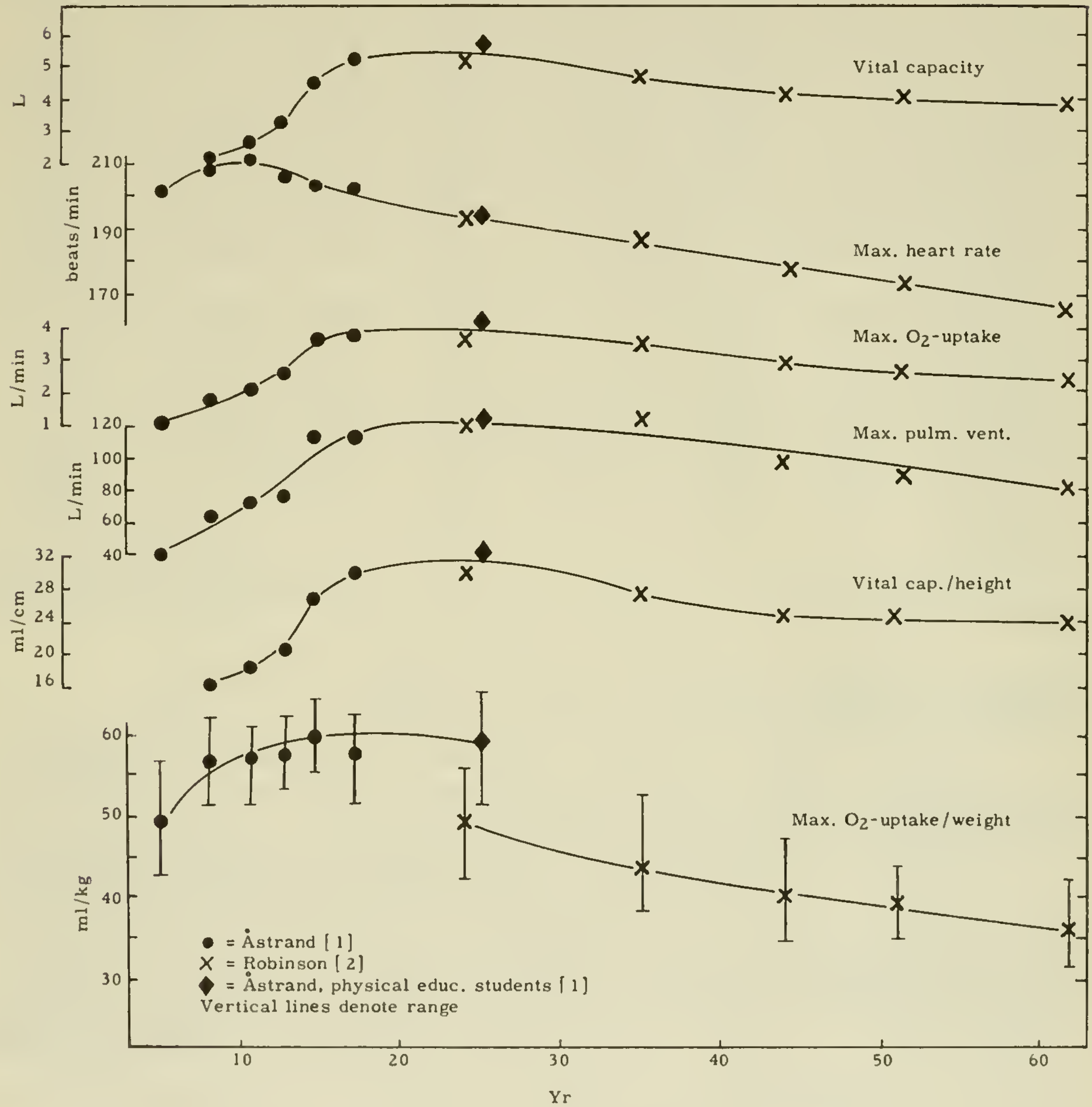
Values are for healthy, well-trained males and females during work on a bicycle ergometer. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Variable	Work Load				
		600 kg-m/min	900 kg-m/min		1200 kg-m/min	1500 kg-m/min
		♀[1]	♂[2]	♀[1]	♂[2]	♂[2]
	(A)	(B)	(C)	(D)	(E)	(F)
1	O_2 uptake, STPD, L/min	1.48(1.36-1.66)	2.09(1.92-2.23)	2.06(1.90-2.24)	2.67(2.43-2.83)	3.33(3.02-3.64)
2	Net efficiency, %	22.5(19.5-24.5)	23.4(22.0-25.5)	23.1(21.3-25.3)	23.7(22.1-26.6)	23.3(21.1-25.7)
3	O_2 uptake, % of maximal[3]	52(43-64)	50(44-61)	73(59-87)	64(52-78)	79(71-96)
4	Heart rate, beats/min	138(120-156)	128(102-148)	168(146-192)	148(130-169)	167(148-188)
5	Ventilation, BTPS, L/min	34.7(25.3-45.6)	41.9(34.6-52.7)	50.6(39.0-62.4)	55.2(42.7-65.6)	70.9(60.2-89.0)
6	Ventilatory equivalent[4]	23.4(18.3-28.3)	20.1(16.4-25.3)	24.5(19.9-29.0)	20.6(15.8-24.7)	21.1(17.8-26.6)
7	Ventilation, % of maximal[5]	39(26-52)	34(27-49)	56(36-73)	45(33-64)	58(49-86)

/1/ 31 subjects. /2/ 21 subjects. /3/ Values calculated as ratio of actual O_2 uptake to maximal O_2 uptake capacity. /4/ Line 5 ÷ Line 1. /5/ Values calculated as ratio of actual ventilation to maximal ventilation capacity.
Contributors: (a) Åstrand, P.-O., (b) Asmussen, E., (c) Suskind, M., (d) Filley, G. F.
Reference: Åstrand, P.-O., "Experimental Studies of Physical Working Capacity in Relation to Sex and Age," Copenhagen: Ejnar Munksgaard, 1952.

104. SUMMARY, EFFECTS OF EXERCISE ON PULMONARY FUNCTION AND HEART RATE: MEN AT VARIOUS AGES

All values obtained over a five- or six-minute period during maximal work on a treadmill or bicycle ergometer.



Contributor: Asmussen, E.

References: [1] Åstrand, P. -O., "Experimental Studies of Physical Working Capacity in Relation to Sex and Age," Copenhagen: Ejnar Munksgaard, 1952. [2] Robinson, S., Arbeitsphysiologie 10:251, 1938.

The oxygen requirement per minute for a given rate of energy expenditure may exceed the oxygen uptake during any given minute if an oxygen debt is being accumulated, resulting in very high values for level running and swimming. Values in parentheses are calculations, assuming one liter of O_2 = 5 Calories. Values for all subjects listed as weighing 70 kg are proportional calculations from values for subjects of other weights.

	Activity	Subjects				Speed		Energy Expenditure	O_2 Requirement	Reference
		No.	Sex	Wt, kg	Remarks	mi/hr	km/hr	Cal/min	L/min	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Resting, supine, basal	5	♂	68	19-25 yr			1.2	(0.238)	1, 2
2		22	♀	55	22 yr			1.0	(0.196)	3
3	Resting, sitting	5	♂	68	19-25 yr			1.8	(0.360)	1, 2
4		22	♀	55	22 yr			1.1	(0.218)	3
5	Resting, standing	5	♂	68	19-25 yr			2.0	(0.396)	1, 2
6		22	♀	55	22 yr			1.1	(0.222)	3
7	Walking, level	2	♂	70	Soldiers	2.3	3.7	3.5	(0.70)	4
8		1	♂	70	Laboratory worker	3.2	5.2	4.5	(0.90)	5
9		2	♂	70	Soldiers	3.5	5.6	4.8	(0.97)	4
10		2	♂	70	Soldiers	4.6	7.4	7.8	(1.57)	4
11	Walking, level,	1	♂	75	Adult	2.5	4.0	4.2	0.85	6
12	treadmill					3.8	6.0	5.6	1.15	
13						5.0	8.0	9.5	1.94	
14						6.3	10.0	17.0	3.47	
15		1	♂	63	Trained athlete	5.0	8.0	7.7	1.57	6
16						6.3	10.0	11.3	2.31	
17						7.5	12.0	15.7	3.21	
	Walking, level									
18	Hard surface road	2	♂	68-69	Carrying 9-kg clothing	3.5	5.5	5.6	1.13	7
19	Grass-covered road				and apparatus	3.5	5.6	6.3	1.28	
20	Furrow in field					3.4	5.4	7.0	1.43	
21	Harvested field					3.3	5.2	6.9	1.41	
22	Plowed field					3.3	5.3	7.7	1.57	
23	Harrowed field					3.2	5.1	10.0	2.05	
24	Hard snow	1	♂	83		3.8	6.0	11.2	2.29	8
25						5.7	9.1	15.8	3.22	
26	Soft snow	1	♂	83	Carrying 20-kg load	2.5	4.0	20.2	4.13	8
27	Walking, level,	5	♂	70	1 miner, 2 athletes,	1.0	1.6	3.5	(0.70)	9
28	carrying 21-kg load				2 sedentary workers	2.0	3.2	4.5	(0.90)	
29						3.0	4.8	5.8	(1.16)	
30						4.0	6.4	9.0	(1.80)	
31	Walking, grade[1], 2.7%	2	♂	70	Soldiers	3.5	5.6	6.1	(1.23)	4
32	uphill 5.0%	1	♂	70	Trained individual	2.0	3.2	4.1	(0.83)	10
33	5.0%	1	♂	70	Trained individual	2.5	4.0	4.8	(0.97)	10
34	5.5%	1	♂	70	Soldier	3.5	5.6	7.5	(1.50)	4
35	6.2%	2	♂	70	Soldiers	3.5	5.6	7.8	(1.56)	4
36	7.3%	2	♂	70	Laboratory workers	3.5	5.6	8.6	(1.73)	4
37	8.3%	1	♂	70	Soldier	3.5	5.6	9.3	(1.87)	4
38	8.6%	2	♂	70	Laboratory workers	2.4	3.8	7.2	(1.43)	4
39	8.6%	64	♂	70	1 marathon runner, 23 sharecroppers, 40 trained individuals	3.5	5.6	9.3	(1.87)	4
40	9.0%	2	♂	70	Soldiers	3.5	5.6	9.3	(1.87)	4
41	10.0%	7	♂	70	Civilian public service workers	3.5	5.6	9.7	(1.93)	11
42	11.8%	2	♂	70	Soldiers	3.5	5.6	11.0	(2.20)	4
43	14.4%	2	♂	70	Soldiers	3.5	5.6	12.3	(2.47)	4
44	Walking, grade[2], 0%	2	♂	70-79		2.6	4.2	3.9-4.4	0.80-0.90	12
45	treadmill, 5%							5.4-5.9	1.10-1.20	
46	uphill 10%							7.4-7.8	1.51-1.60	
47	15%							9.7-10.3	1.98-2.10	
48	20%							12.2-13.0	2.48-2.65	
49	25%							14.7-15.8	3.00-3.23	
50	Walking, grade[2], 0%	2	♂	70-79		2.6	4.2	3.9-4.4	0.80-0.90	12
51	treadmill, 5%							3.4-3.7	0.70-0.76	
52	downhill 10%							3.3-3.6	0.68-0.73	
53	15%							3.7-3.8	0.75-0.77	
54	20%							4.2-4.3	0.85-0.88	
55	25%							4.8-4.9	0.97-1.00	

/1/ Grade = the distance the body rises, expressed in per cent of the distance travelled. /2/ Grade = 5% for each 29° of incline.

The oxygen requirement per minute for a given rate of energy expenditure may exceed the oxygen uptake during any given minute if an oxygen debt is being accumulated, resulting in very high values for level running and swimming. Values in parentheses are calculations, assuming one liter of O_2 = 5 Calories. Values for all subjects listed as weighing 70 kg are proportional calculations from values for subjects of other weights.

	Activity	Subjects				Speed		Energy Expenditure Cal/min	O_2 Requirement L/min	Reference
		No.	Sex	Wt, kg	Remarks	mi/hr	km/hr			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
56	Walking, 35.8% grade[1],	5	♂	70	1 miner, 2 athletes, 2	0.5	0.8	6.2	(1.23)	9
57	carrying 21-kg load				sedentary workers	1.0	1.6	11.3	(2.27)	
58						1.5	2.4	14.0	(2.81)	
59	Running, level	2	♂	70	Soldiers	5.7	9.2	12.0	(2.40)	4
60						6.9	11.0	14.5	(2.90)	
61		1	♂	70	Athlete[3]	11.4	18.4	21.7	(4.33)	13
62						13.2	21.1	38.8	(7.77)	
63						14.6	23.5	44.7	(8.93)	
64						14.8	23.7	48.0	(9.60)	
65						15.8	25.3	65.2	(13.03)	
66						17.2	27.7	79.0	(15.80)	
67						18.6	29.8	129.8	(25.57)	
68						18.9	30.4	158.0	(31.60)	
69	Running, level,	1	♂	74	Running, at "steady	7.5	12.0	15.7	3.20	14
70	treadmill[4]				state"	8.8	14.0	18.1	3.70	
71						10.0	16.0	21.1	4.30	
72						11.3	18.0	25.0	5.10	
73						12.5	20.0	33.3	6.80	
74	Running, level,	1	♂	75	Running 800 meters	12.0	19.2	34.8	7.10	15
75	on track[4]	1	♂	74	Running 400 meters	16.4	26.3	89.6	18.30	15
76		1	♂	70	Running 200 meters	17.6	28.1	160.9	32.85	15
77		1	♂	72	Running 100 meters	18.0	28.8	227.2	46.40	16
78	Running, 8.6% grade[1]	25	♂	70	1 marathon runner, 12 adults, 12 boys	5.8	9.3	12.6	(2.53)	4
79		64	♂	70	1 marathon runner, 23 sharecroppers, 40 trained individuals	7.0	11.3	15.8	(3.17)	4
80	Bicycling, level	1	♂	70	Laboratory worker on	5.5	8.9	3.2	(0.63)	17
81					bicycle weighing 21	9.4	15.1	5.8	(1.17)	
82					kg	13.2	21.3	10.0	(2.00)	
83	Bicycling, 3.5% grade[2],	1	♂	85	Well-trained individual	6.3	10.0	7.8	1.60	18
84	treadmill, uphill				on bicycle weighing	7.5	12.0	8.8	1.80	
85					17 kg	8.8	14.0	10.1	2.05	
86						10.0	16.0	11.3	2.30	
87						11.3	18.0	12.8	2.60	
88						12.5	20.0	14.2	2.90	
89						13.8	22.0	16.2	3.30	
90	Bicycling, grade, 2%	1	♂	79	On bicycle weighing	5.4	8.6	6.0	1.22	12
91	treadmill, 4%				16 kg			8.7	1.77	
92	uphill 6%							11.4	2.33	
93	8%							14.1	2.88	
94	10%							16.9	3.45	
95	Bicycling, grade, 2%	1	♂	79	On bicycle weighing	5.4	8.6	2.5	0.51	12
96	treadmill, 4%				16 kg			2.9	0.59	
97	downhill 6%							3.3	0.67	
98	8%							3.7	0.75	
99	10%							4.1	0.83	
100	12%							4.4	0.90	
101	Free-wheeling							2.4	0.48	
102	Rowing, calm water	3	♂	70	Laboratory workers in	2.0	3.2	4.8	(0.97)	19
103					rowboat with assist-	2.5	4.0	6.5	(1.30)	
104					ant; 2 oars used	3.0	4.8	8.7	(1.73)	
105						3.5	5.6	11.0	(2.50)	
106	Rowing machine	1	♂	70	Expert oarsmen in ex-	10.9	17.4	16.2	(3.23)	20
107	ergometer	3	♂	70	cellent condition; 1	11.3	18.1	18.8	(3.77)	
108		1	♂	70	oar used[3]	12.0	19.2	25.0	(5.00)	
109	Skating, smooth ice	2	♂	70	Laboratory workers;	9.0	14.5	7.8	(1.57)	21
110					skating skill, good	11.0	17.6	10.3	(2.07)	

/1/ Grade = the distance the body rises, expressed in per cent of the distance travelled. /2/ Grade = 5% for each 2.9° of incline. /3/ O_2 debt included in values given for this subject. /4/ O_2 determination from total O_2 uptake in work and recovery.

The oxygen requirement per minute for a given rate of energy expenditure may exceed the oxygen uptake during any given minute if an oxygen debt is being accumulated, resulting in very high values for level running and swimming. Values in parentheses are calculations, assuming one liter of O_2 = 5 Calories. Values for all subjects listed as weighing 70 kg are proportional calculations from values for subjects of other weights.

	Activity	Subjects				Speed		Energy Expenditure Cal/min	O_2 Requirement L/min	Reference
		No.	Sex	Wt, kg	Remarks	mi/hr	km/hr			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
111	Skating, smooth ice (concluded)	2	♂	70	Laboratory workers; skating skill, good	13.0	20.9	13.0	(2.60)	21
112	Skiing, level	1	♂	83	Skiing, at "steady state" on loose snow	2.6	4.2	8.3	1.69	8
113						3.9	6.3	11.5	2.34	
114						5.3	8.4	14.8	3.02	
115						6.7	10.7	15.4	3.14	
116						8.2	13.1	21.6	4.41	
117						9.2	14.7	25.7	5.24	
118	Skiing, level, carrying 20-kg load	1	♂	83	Skiing, at "steady state" on loose snow	2.5	4.0	12.6	2.57	8
119	Skiing, 16.7% grade[2], uphill	1	♂	83	Skiing, at "steady state" on loose snow	1.8	2.8	13.9	2.84	8
120	Snow-shoeing, level	2	♂	70	Soldiers on bearpaw snow-shoes; skill, fair	2.5	4.0	8.7	(1.73)	4
121					Mountaineers on bearpaw snow-shoes; skill, good	2.6	4.2	12.3	(2.47)	4
122		4	♂	70	2 soldiers; skill, fair. 2 mountaineers; skill, good. All on trail snow-shoes.	2.5	4.0	10.3	(2.07)	4
123		1	♂	70	Mountaineer on trail snow-shoes; skill, good	3.5	5.6	14.8	(2.97)	4
124		1	♂	83		2.5	4.0	13.8	2.82	8
125	Snow-shoeing, level, carrying 20-kg load	1	♂	83		2.5	4.0	15.0	3.06	8
126	Snow-shoeing, 16.7% grade[2]	1	♂	83		1.8	2.8	16.4	3.34	8
127	Swimming, breast stroke, up to 3-min duration	1	♂	70	Laboratory worker; skill, good	1.0	1.6	6.8	(1.37)	22
128		6	♂	70	Laboratory workers; skill, 4 good, 2 fair	1.6	2.6	8.2	(1.63)	22
129		1	♂	70	Athlete; skill, good[3]	1.9	3.0	13.7	(2.73)	23
130						2.2	3.5	30.8	(6.17)	
131						2.4	3.8	42.2	(8.43)	
132						2.7	4.3	61.5	(12.30)	
133	Swimming, breast stroke, "steady state"	1	♂		Excellent swimmer	0.6	1.0	6.9	1.41	24
134						0.9	1.4	7.7	1.58	
135						1.2	1.9	9.9	2.02	
136						1.5	2.4	12.6	2.57	
137						1.8	2.9	16.0	3.26	
138						2.1	3.4	19.6	4.00	
139	Swimming, breast stroke, short sprint[4]	1	♂		Good swimmer, sprinting 20-40 meters	2.2	3.6	38.0	7.75	25
140						2.6	4.1	58.0	11.80	
141	Swimming, crawl stroke, "steady state"	1	♂		Excellent swimmer	1.4	2.2	9.4	1.92	24
142						1.7	2.6	11.9	2.42	
143						2.0	3.1	14.4	2.94	
144						2.2	3.5	16.2	3.30	
145	Swimming, crawl stroke, short sprint[4]	1	♂		Good swimmer, sprinting 20-40 meters	2.2	3.6	22.0	4.50	25
146						2.6	4.1	29.0	5.90	
147						2.9	4.6	39.0	8.00	
148						3.2	5.0	50.0	10.20	
149						3.5	5.6	67.0	13.70	
150						3.8	6.0	95.0	19.40	

/2/ Grade = 5% for each 2.9° of incline. /3/ O_2 debt included in values given for this subject. /4/ O_2 determination from total O_2 uptake in work and recovery.

Contributors: (a) Riley, R. L., and Johns, C. J., (b) Morehouse, L. E., and Cherry, R. B., (c) Asmussen, E., (d) Chapin, J. L., (e) Douglas, C. G.

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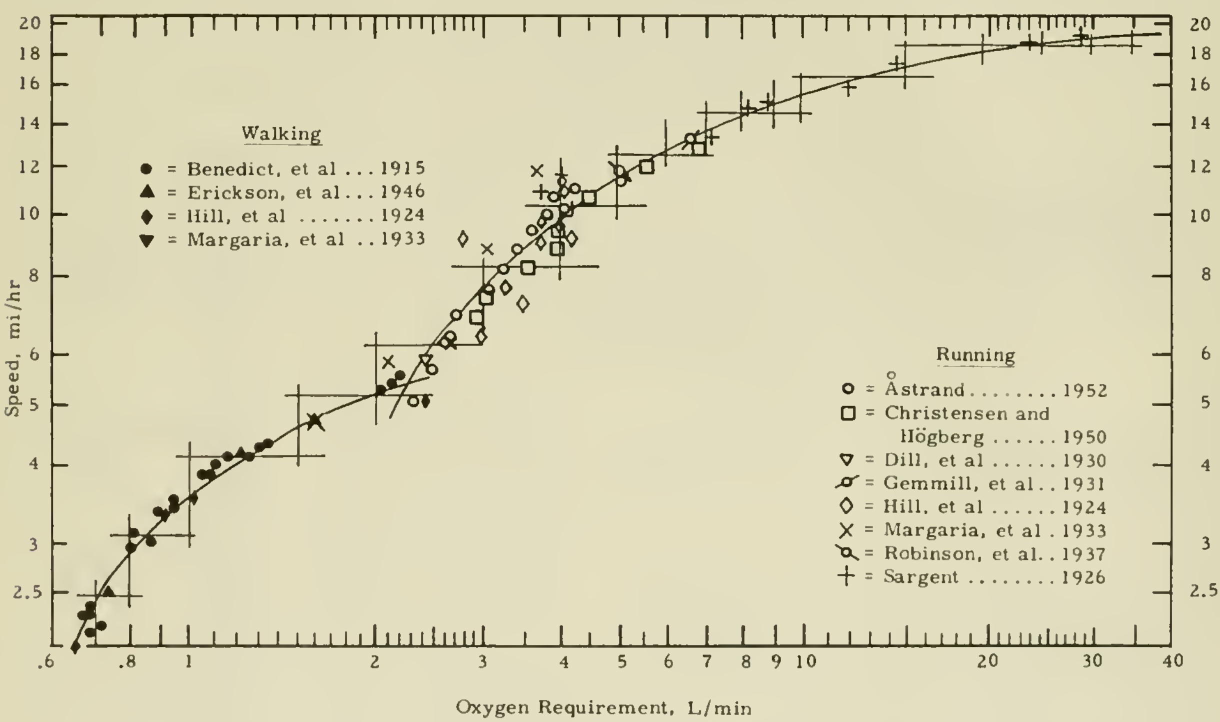
106. O_2 REQUIREMENT AT VARIOUS RUNNING AND WALKING SPEEDS: MEN



Contributor: Henry, F. M.

107. EFFECT OF BREATHING N_2 ON RESPIRATORY RATE, TIDAL AND MINUTE VOLUMES: MAN

	Breath[1] no.	Respiratory Rate breaths/min	Tidal Volume ml	Minute Volume L/min	Minute Volume Ratio[2]: Experimental / Control
	(A)	(B)	(C)	(D)	(E)
1	1	16.4	370	0.62	
2	4	17.2	550	0.99	1.60
3	7	16.2	1063	1.63	2.63
4	10	19.8	1111	2.25	3.63
5	13	19.5	704	1.69	2.74

/1/ Breathing was continuous. /2/ "Experimental" refers to any pulmonary ventilation after the first breath; "control" refers to volume of the first breath.

Contributor: Swann, H. G.

Reference: Lutz, B. R., and Schneider, E. C., Am. J. Physiol. 50:336, 1920.

108. EFFECT OF BREATHING N_2 ON RESPIRATORY RATE AND MINUTE VOLUME: DOG

	Time of Exposure min	Respiratory Rate per min	Respiratory Rate Ratio[1]: Experimental / Control	Minute Volume L/min	Minute Volume Ratio[1]: Experimental / Control
	(A)	(B)	(C)	(D)	(E)
1	At rest[2]	13.0		4.9	
2	0.1			8.0	1.63
3	0.3	23.5	1.7	10.3	2.10
4	0.5			13.5	2.76
5	0.7	29.0	2.2	17.0	3.47
6	0.9			12.5	2.55
7	1.1	20.5	1.6	9.0	1.84

/1/ "Experimental" refers to ventilation after exposure to N_2; "control" refers to breathing during the first minute before exposure to N_2. /2/ Minute before exposure to N_2.

Contributor: Swann, H. G.

Reference: Swann, H. G., Engineering Division, ATSC, USAAF, Report No. TSEAL-696-79B, p 31, Oct., 1945.

109. PULMONARY FUNCTION: RESIDENTS AND NEWCOMERS AT HIGH ALTITUDES

Altitude = 13,090 ft (478 mm Hg), except for Line 1. Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Residence	Respiratory Rate breaths/min	Minute Volume L/min	Alveolar Air pO_2, mm Hg	Alveolar Air pCO_2, mm Hg	Respiratory Quotient	O_2 Consumption L/min
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Sea level	12.1	6.9(6.1-7.7)	97.9(93.5-102.3)	40.8(38.6-43.0)	0.864(0.842-0.886)	
2	2-8 da[1]	16.8	9.6(8.8-10.4)	50.4(48.4-52.4)	32.1(31.4-32.8)	0.826(0.782-0.870)	257.2(230.0-284.4)
3	14-54 da[1]	16.1	9.2(8.4-10.0)	53.6(51.6-55.6)	31.1(28.8-33.4)	0.831(0.801-0.861)	246.8(239.0-254.6)
4	6-23 yr[2]	13.6	7.5(6.9-8.1)	48.1(44.6-51.6)	34.7(33.0-36.4)	0.847(0.821-0.873)	243.6(229.8-257.4)

/1/ Sea level residents tested during brief stay at altitude. /2/ Residents born in the Andean altiplano and living at 13,090 ft for 6 yr or more.

Contributor: Swann, H. G.

Reference: Chiodi, H., J. Appl. Physiol. 10:82, 1957.

110. BLOOD GASES: RESIDENTS AND NEWCOMERS AT HIGH ALTITUDES

Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Altitude[1] ft	Altitude[1] m	Altitude[1] mm Hg	Oxygen Pressure mm Hg	Oxygen Content[2] ml/100 ml	Oxygen Capacity[2] ml/100 ml	Oxygen Saturation %	Carbon Dioxide Pressure mm Hg	Carbon Dioxide Content ml/100 ml	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Permanent Residents									
1	492	150	746	90	20.7	21.7	95.4	41	46	D-I,1
2	7840	2390	568	68	21.2(18.5-24)	23.1(19-27.5)	91.7(86.5-97)	37.8(34-42)	41.1(37-45)	D-I,2
3	10,300	3140	517	66	21.8(19-25)	24.0(22-26)	91.0(87-95)	36.4(31-42)	39.3(34.5-44)	D,1;E-I,2
4	12,238	3730	479	57	21.9(18.5-25)	25.0(21.5-28.5)	87.6(84.5-91.5)		36.0(33-39)	D,1;E-G, I,2
5	14,896	4540	431	47	23.0(19.5-26.5)	28.3(24-32.5)	81.4(75.5-87)	34.7(29-40)	33.5(32-35)	D,1;E-I,2
6	15,950	4860	413	46	23.4(20.5-26.5)	29.0(25-33)	80.7(76-85)	33.0(28-38)	34.0(31-37)	D,1;E-I,2
7	17,521	5340	387	43	23.0	30.2	76.2	29.3	31.8	D-I,3
	Newcomers[3]									
8	11,319	3450	496	55	20.5	24.1	85	31	41	D-I,4
9	15,421	4700	429	44	18.7[4]	24.1[4]	78	29.3	38.3	D,G-I,3
10	17,521	5340	387	43	18.6[4]	24.5[4]	76.2	27.7	35.0	D,G-I,3
11	20,145	6140	347	35	16.3[4]	24.9[4]	65.6	24.2	30.2	D,G-I,3

/1/ U. S. standard atmosphere. /2/ Combined O_2 only; does not include physically dissolved O_2. /3/ Up to 16 da. /4/ Derived by interpolation.

Contributors: (a) Adler, H. F., and Luft, U. C., (b) Penrod, K. E., (c) Swann, H. G.

References: [1] National Research Council CAM Report, "Handbook of Respiratory Data in Aviation," Charts A-1, B-1, B-3, prepared from data of the Aero-Medical Laboratory, Wright Field, and The Johnson Foundation, Washington, D. C., 1944. [2] Hurtado, A., and Aste-Salazar, H., J. Appl. Physiol. 1:304, 1948. [3] Dill, D. B., Christensen, E. H., and Edwards, H. T., Am. J. Physiol. 115:530, 1936. [4] Becker-Freysend, H., Loeschcke, H. H., Luft, U. C., and Opitz, E., Luftfahrtmedizin 7:160, 1942.

111. EFFECT OF REDUCED BAROMETRIC PRESSURES ON PULMONARY FUNCTION AND HEART RATE: MAN

Eight trained subjects, seated and breathing air through a face mask from a Pioneer demand valve, in a high altitude chamber. After 20-minute period at ground level (540 feet above sea level), during which control measurements were made, ascent to desired altitude occurred at rate of 4500 feet per minute. Each subject was exposed from ground level to experimental level, with at least a one-day interval between successive exposures. Values are averages.

	Exposure Time min	Alveolar pO_2 mm Hg	Alveolar pCO_2 mm Hg	Alveolar R.Q.[1]	Minute Volume[2] L/min	Respiratory Rate breaths/min	Arterial HbO_2 Calc.[3] %	Arterial HbO_2 Oxim.[4] %	O_2 Consumption[5] L/min	Heart Rate[6] %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Ground Level (B = 746 mm Hg)									
1	5	102.2	37.0	0.82	8.80	13			0.314	
2	10	100.8	37.2	0.80	9.10	14			0.334	
3	15	101.5	36.8	0.81	9.02	14			0.327	82[7]
4	20	101.1	37.6	0.81	8.85	13		98	0.324	100
	12,000 ft (B = 483 mm Hg)									
5	5	54.5	35.1	0.95	10.60	16	89	89	0.312	
6	10	52.1	35.4	0.89	9.45	14	88	87	0.302	113
7	15	51.2	35.1	0.86	9.82	14	87	85	0.327	
8	20	51.0	35.1	0.85	9.48	13	87	86	0.319	115
9	25	50.0	35.2	0.83	9.42	14	86	85	0.321	
10	30	50.4	34.9	0.85	9.50	14	87	85	0.313	113
11	35	49.5	35.3	0.83	9.53	14	86	84	0.326	
12	40	51.4	34.5	0.83	9.66	14	88	85	0.325	106
13	45	51.2	34.3	0.83	9.72	14	87	85	0.326	
14	50	50.9	34.3	0.83	9.61	14	87	85	0.317	104
15	55	49.4	35.1	0.81	9.80	15	86	85	0.336	
16	60	50.7	34.0	0.82	9.77	14	87	85	0.331	99
	Ground Level (B = 751 mm Hg)									
17	5	107.1	35.1	0.86	8.69	11			0.301	
18	10	107.9	34.6	0.87	8.69	12			0.281	
19	15	107.0	34.9	0.83	8.61	12			0.297	81[7]
20	20	106.1	34.9	0.83	8.25	13			0.275	100
	16,000 ft (B = 412 mm Hg)									
21	5	46.1	32.4	1.11	9.50	12	85	82	0.233	
22	10	45.6	30.8	1.03	9.32	12	85	80	0.225	111
23	15	44.4	30.8	0.99	8.98	11	84	78	0.244	
24	20	44.8	30.0	0.96	9.14	11	84	79	0.244	110
25	25	46.1	28.5	0.98	9.40	11	85	79	0.236	
26	30	45.4	28.6	0.95	9.74	13	85	79	0.248	103
27	35	44.4	28.9	0.91	9.36	12	84	80	0.248	
28	40	43.2	29.4	0.87	8.79	12	83	78	0.250	103
29	45	44.2	28.6	0.89	9.76	12	84	80	0.270	
30	50	44.4	28.2	0.87	9.39	12	85	81	0.254	101
31	55	43.5	27.9	0.82	8.90	13	84	79	0.258	
32	60	44.2	28.0	0.86	10.50	11	84	82	0.306	105
	Ground Level (B = 751 mm Hg)									
33	5	108.2	34.6	0.88	8.55	12			0.275	
34	10	105.3	34.9	0.82	8.45	11			0.304	
35	15	105.5	34.8	0.82	8.49	12			0.294	82[7]
36	20	107.1	35.0	0.86	8.42	12			0.279	100

/1/ As calculated by equation from Fenn, W. O., Rahn, H., and Otis, A. B., Am. J. Physiol. 146:639, 1946. /2/ Calculated at BTPS. /3/ Per cent saturation of arterial blood as estimated from alveolar pCO_2 and pO_2 with the nomogram of L. J. Henderson, 1928. /4/ Per cent saturation of arterial blood as indicated by the Millikan oximeter. /5/ At STP, calculated from O_2 consumption $= \frac{Va \times pC}{0.864 \times Q}$, where Va = alveolar ventilation in L/min, BTPS; pC = alveolar pCO_2 in mm Hg; Q = alveolar respiratory quotient; $0.864 = \frac{310}{273} \times \frac{760}{1000}$. A constant dead space of 210 cc was assumed in computing Va from total ventilation (150 cc personal dead space, plus 60 cc apparatus dead space). /6/ As per cent of resting heart rate at ground level. These values are averages based on several measurements during each indicated 10-min period. /7/ Average value for control rate in beats/min.

111. EFFECT OF REDUCED BAROMETRIC PRESSURES ON PULMONARY FUNCTION AND HEART RATE: MAN (Concluded)

	Exposure Time min	Alveolar pO_2 mm Hg	Alveolar pCO_2 mm Hg	Alveolar R.Q.[1]	Minute Volume[2] L/min	Respiratory Rate breaths/min	Arterial Hb O_2 Calc.[3] %	Arterial Hb O_2 Oxim.[4] %	O_2 Consumption[5] L/min	Heart Rate[6] %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	18,000 ft (B = 379 mm Hg)									
37	5	44.1	28.8	1.23	11.38	11	84	80	0.246	
38	10	43.1	28.4	1.15	10.90	11	84	79	0.246	107
39	15	41.8	28.0	1.06	11.02	11	82	77	0.266	
40	20	41.3	28.3	1.02	11.24	12	82	78	0.271	109
41	25	41.5	26.6	0.99	11.24	12	82	75	0.271	
42	30	40.1	27.0	0.94	11.06	11	81	75	0.292	108
43	35	40.1	26.7	0.93	11.10	11	81	76	0.292	
44	40	40.8	26.2	0.93	11.73	11	82	76	0.307	111
45	45	40.2	25.7	0.90	11.43	12	81	77	0.296	
46	50	39.8	26.2	0.88	10.66	12	81	77	0.282	108
47	55	40.3	25.4	0.88	10.63	12	82	76	0.272	
48	60	41.1	25.1	0.90	10.83	11	83	78	0.275	104
	Ground Level (B = 745 mm Hg)									
49	5	104.1	36.5	0.85	8.30	13			0.278	
50	10	104.2	35.1	0.85	8.71	12			0.297	
51	15	100.7	37.0	0.79	8.12	11			0.315	84[7]
52	20	104.8	35.5	0.85	8.40	11			0.296	100
	20,000 ft (B = 349 mm Hg)									
53	5	39.8	27.1	1.21	13.77	11	81	78	0.298	
54	10	37.6	26.6	1.03	12.36	11	79	74	0.301	124
55	15	36.8	26.3	0.97	12.66	11	78	74	0.325	
56	20	36.7	24.4	0.94	11.76	11	78	73	0.284	112
57	25	36.4	25.6	0.93	12.23	12	78	72	0.310	
58	30	36.4	24.4	0.94	12.46	12	80	74	0.299	117
59	35	36.8	24.5	0.89	12.60	12	79	75	0.321	
60	40	37.9	23.4	0.89	13.44	13	80	77	0.326	107
61	45	39.0	23.2	0.84	12.56	13	79	76	0.315	
	Ground Level (B = 747 mm Hg)									
62	5	105.0	34.7	0.83	8.72	10			0.321	
63	10	103.9	35.2	0.81	8.18	11			0.296	
64	15	102.9	35.5	0.82	8.57	11			0.315	
65	20	103.3	35.3	0.81	8.64	11			0.320	100
	22,000 ft (B = 321 mm Hg)									
66	5	36.1	24.4	1.26	16.79	14	78	73	0.311	
67	10	34.0	25.1	1.11	14.61	12	75	68	0.317	131
68	15	33.6	23.8	1.05	15.82	14	75	69	0.338	
69	20	32.7	24.6	1.01	15.21	14	73	66	0.347	126
70	25	31.8	24.1	0.95	14.15	14	72	63	0.330	
71	30	32.0	23.5	0.95	15.31	15	72	64	0.359	124

/1/ As calculated by equation from Fenn, W. O., Rahn, H., and Otis, A. B., Am. J. Physiol. 146:639, 1946. /2/ Calculated at BTPS. /3/ Per cent saturation of arterial blood as estimated from alveolar pCO_2 and pO_2 with the nomogram of L. J. Henderson, 1928. /4/ Per cent saturation of arterial blood as indicated by the Millikan oximeter. /5/ At STP; calculated from O_2 consumption = $\frac{Va \times pC}{0.864 \times Q}$, where Va = alveolar ventilation in L/min, BTPS; pC = alveolar pCO_2 in mm Hg; Q = alveolar respiratory quotient; $0.864 = \frac{310}{273} \times \frac{760}{1000}$. A constant dead space of 210 cc was assumed in computing Va from total ventilation (150 cc personal dead space, plus 60 cc apparatus dead space). /6/ As per cent of resting heart rate at ground level. These values are averages based on several measurements during each indicated 10-min period. /7/ Average value for control rate in beats/min.

Contributors: (a) Ivy, A. C., (b) Marbarger, J. P., (c) Swann, H. G., (d) Wechsberg, P.

Reference: Air Force Tech. Rept. No. 6528, Aug. 1951.

112. EFFECT OF REDUCED BAROMETRIC PRESSURES AND CO_2 INHALATION ON PULMONARY FUNCTION AND HEART RATE: MAN

Four trained subjects, seated and breathing air through a face mask from a Pioneer demand valve in a high altitude chamber at simulated altitude of 16,000 feet. After control period of 10 minutes, subjects breathed 6% CO_2 in air for 15 minutes, followed by 10-minute recovery period also at 16,000 feet. Values are averages.

	Condition	Exposure Time min	Alveolar pO_2 mm Hg	Alveolar pCO_2 mm Hg	Alveolar R. Q.[1]	Minute Volume[2] L/min	Respiratory Rate breaths/min	Arterial Hb O_2 Calc.[3] %	Arterial Hb O_2 Oxim.[4] %	Heart Rate[5] %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Control	2	49.0	32.0	1.22	13.87	11	88	87	
2		4	47.8	30.9	1.13	12.36	12	87	86	
3		6	47.2	30.9	1.11	12.73	11	86	85	
4		8	47.9	30.0	1.09	13.87	10	87	86	
5		10	46.4	30.5	1.05	12.14	10	85	84	87
6	6% CO_2	2	46.1	36.3	0.89	12.79	11	84	84	
7		4	47.4	40.0	0.72	13.80	12	84	85	
8		6	47.7	40.2	0.77	15.16	14	84	85	
9		8	48.1	41.4	0.82	15.10	12	83	85	
10		10	48.9	41.2	0.82	15.45	13	84	84	
11		12	49.3	41.4	0.86	15.09	14	85	84	
12		14	49.2	41.5	0.85	15.96	14	85	84	
13		15	49.4	41.5	0.85	15.37	13	85	84	79
14	Recovery	2	47.9	35.7	1.39	14.95	13	86	85	
15		4	46.4	32.2	1.12	12.56	12	86	82	
16		6	46.2	31.9	1.13	12.07	11	85	82	
17		8	45.4	31.9	1.07	12.10	11	85	81	
18		10	45.9	31.7	1.08	11.83	10	85	81	83
					Summary					
19	Control		47.9	30.9	1.12	12.99	11	87	85	87
20	6% CO_2		48.3	40.4	0.82	14.84	13	84	84	79
21	Recovery		46.4	32.7	1.16	12.70	11	85	82	83

/1/ Alveolar respiratory quotient as calculated by equation from Fenn, W. O., Rahn, H., and Otis, A. B., Am. J. Physiol. 146:639, 1946. /2/Calculated at BTPS. /3/ Per cent saturation of arterial blood as estimated from alveolar pCO_2 and pO_2 with the nomogram of L. J. Henderson, 1928. /4/ Per cent saturation of arterial blood as indicated by the Millikan oximeter. /5/ As per cent of resting heart rate at ground level. Values are averages based on several measurements during each period.

Contributors: (a) Ivy, A. C., (b) Marbarger, J. P., (c) Swann, H. G., (d) Wechsberg, P.

Reference: Air Force Tech. Rept. No. 6528, Aug. 1951.

113. EFFECT OF REDUCED BAROMETRIC PRESSURES AND EXERCISE ON PULMONARY FUNCTION AND HEART RATE: MAN

Eight trained subjects, seated and breathing air through a face mask from a Pioneer demand valve, in a high altitude chamber. At ground level and at simulated altitude of 16,000 feet, subjects engaged in muscular work, pushing feet alternately against pedals constructed from flat pieces of spring steel, at rate of 30 times a minute for each foot. The mechanical work required for this task was calculated to be 49.4 kilogram-meters per minute. Work period of 10 minutes was preceded by a 10-minute control period and followed by a 10-minute recovery period. Values are averages.

	Condition	Exposure Time min	Alveolar pO_2 mm Hg	Alveolar pCO_2 mm Hg	Alveolar R. Q.[1]	Minute Volume[2] L/min	Respiratory Rate breaths/min	Arterial Hb O_2 Calc.[3] %	Arterial Hb O_2 Oxim.[4] %	O_2 Consumption[5] L/min	Heart Rate[6] %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
	Ground Level (B = 746 mm Hg)										
1	Control	2	101.3	37.7	0.83	9.12	12			0.349	
2		4	101.5	37.8	0.82	8.72	12			0.332	
3		6	101.7	38.0	0.86	8.63	12			0.314	
4		8	102.2	37.3	0.85	8.79	12			0.320	
5		10	100.1	38.5	0.83	9.06	12			0.353	84
6	Work	2	94.5	41.7	0.79	12.18	15			0.548	
7		4	96.9	41.4	0.83	13.83	14			0.632	
8		6	97.6	41.3	0.83	13.99	15			0.622	
9		8	98.7	41.3	0.86	14.85	15			0.661	
10		10	98.5	41.0	0.84	13.94	16			0.595	92
11	Recovery	2	102.8	37.7	0.87	10.81	13			0.407	
12		4	101.9	38.0	0.86	8.85	13			0.315	
13		6	102.4	37.5	0.85	8.89	13			0.316	
14		8	102.0	37.5	0.84	8.81	13			0.315	
15		10	102.8	36.7	0.84	8.76	13			0.306	87
	16,000 ft (B = 412 mm Hg)										
16	Control	2	46.6	33.6	1.19	11.07	12	85	81	0.280	
17		4	44.6	33.8	1.12	11.46	12	83	80	0.313	
18		6	44.2	33.6	1.08	11.09	12	83	78	0.320	
19		8	43.4	33.3	1.04	11.09	12	82	78	0.319	
20		10	43.0	33.4	1.02	11.38	11	82	78	0.344	95
21	Work	2	41.0	35.3	1.02	16.01	14	78	74	0.526	
22		4	40.6	35.2	1.00	17.65	15	78	73	0.589	
23		6	40.1	35.3	0.97	17.63	15	78	73	0.607	
24		8	39.6	35.3	0.97	17.65	15	77	72	0.609	
25		10	39.8	34.9	0.97	17.58	17	78	71	0.594	107
26	Recovery	2	41.6	33.3	0.96	13.11	12	80	74	0.426	
27		4	41.3	33.3	0.95	10.98	13	80	74	0.348	
28		6	41.6	33.5	0.96	10.11	11	80	76	0.316	
29		8	41.0	32.6	0.92	9.99	12	80	76	0.307	
30		10	40.8	33.2	0.94	10.25	11	79	75	0.325	92
	Summary, Ground Level										
31	Control		101.4	37.9	0.84	8.86	12			0.334	84
32	Work		97.2	41.3	0.83	13.76	15			0.612	92
33	Recovery		102.4	37.5	0.85	9.22	13			0.332	87
	Summary, 16,000 ft										
34	Control		44.4	33.5	1.09	11.22	12	83	79	0.309	95
35	Work		40.2	35.2	0.99	17.30	15	78	73	0.583	107
36	Recovery		41.3	33.2	0.95	10.89	12	80	75	0.344	92

/1/ Alveolar respiratory quotient as calculated by equation from Fenn, W. O., Rahn, H., and Otis, A. B., Am. J. Physiol. 146:639, 1946. /2/ Calculated at BTPS. /3/ Per cent saturation of arterial blood as estimated from alveolar pCO_2 and pO_2 with the nomogram of L. J. Henderson, 1928. /4/ Per cent saturation of arterial blood as indicated by the Millikan oximeter. /5/ At STP, calculated from O_2 consumption = $\frac{Va \times pC}{0.864 \times Q}$, where Va = alveolar ventilation in L/min, BTPS; pC = alveolar pCO_2 in mm Hg; Q = alveolar respiratory quotient; $0.864 = \frac{310}{273} \times \frac{760}{1000}$. A constant dead space of 210 cc was assumed in computing Va from total ventilation (150 cc personal dead space, plus 60 cc apparatus dead space). /6/ As per cent of resting heart rate at ground level. These values are averages based on several measurements during each indicated 10-min period.

Contributors: (a) Ivy, A. C., (b) Marbarger, J. P., (c) Swann, H. G., (d) Wechsberg, P.

Reference: Air Force Tech. Rept. No. 6528, Aug. 1951.

114. EFFECT OF ACCLIMATIZATION TO REDUCED BAROMETRIC PRESSURES ON PULMONARY FUNCTION: MAN

Slow decompression over period of one month to an equivalent altitude of about 21,000 ft. Exercise on stationary bicycle at 2530 ft-lb per min, except at altitudes above 20,000 ft where the rate was reduced to 1490 ft-lb per min. Averages of 4 subjects, except at 21,000-22,000 ft, when 3 subjects were observed. PV = pulmonary ventilation.

	Day of Ascent	Altitude x 1000 ft	Pressure mm Hg	Respiratory Rate breaths/min		Pulmonary Ventilation L/min		Ventilation Ratios		Arterial Blood						Respiratory Quotient	
								PV at Altitude / PV at Sea Level (At Rest)	PV in Exercise / PV at Rest (At Altitude)	pO_2 mm Hg		pCO_2 mm Hg		pH			
				Rest	Exercise	Rest	Exercise			Rest	Exercise	Rest	Exercise	Rest	Exercise	Rest	Exercise
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)
1	0	Sea level	760	12.0	18.0	6.8	24.0		3.5	90	94	42	44	7.40	7.39	0.831	0.910
2	6-9	9-12	543-483	11.5	22.8	9.3	36.8	1.4	4.0	60	54	30	33	7.46	7.47	0.834	0.950
3	11-14	14-16	446-412	12.5	20.8	10.3	41.3	1.5	4.0	46	41	28	28	7.50	7.47	0.830	0.924
4	16-19	17.5-18.5	388-370	13.0	24.5	11.8	47.3	1.7	4.0	40	34	22	24	7.52	7.47	0.809	0.941
5	19-22	19-20	364-349	10.8	24.5	12.3	49.8	1.8	4.0	37	32	22	22	7.51	7.48	0.838	0.948
6	24-26	21-22	335-321	15.3	21.3	14.3	47.3	2.1	3.3	32	31	22	21	7.51	7.52	0.854	0.937

Contributor: Swann, H. G.

Reference: Houston, C. S., and Riley, R. L., Am. J. Physiol. 149:565, 1947.

115. EFFECT OF REDUCED BAROMETRIC PRESSURES AND EXERCISE ON VENTILATION: MAN

Ratio A = load performance at given altitude to rest performance at sea level; Ratio B = load performance at given altitude to rest performance at same altitude; Alt = altitude, SL = sea level.

	Altitude x 1000 ft	Pressure mm Hg	Ratio Type	Respiratory Rate Ratios					Ventilation Ratios					Reference
				Rest at Alt / Rest at SL	Load / Rest				Rest at Alt / Rest at SL	Load / Rest				
				Load in ft-lb/min					Load in ft-lb/min					
				0	357	2000	4000	6000	0	357	2000	4000	6000	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)
1	SL	746-760	A		1.3	1.3	1.6	1.8	1.0	1.6	2.7	4.7	6.3	1
2	10	523	A	1.0		1.6	1.9	2.2	1.0		3.0	5.1	7.2	1
3		523	B			1.2	1.2	1.2			1.1	1.1	1.1	1
4	15	429	A	1.0		1.6	2.0	2.3	1.0		3.3	5.8	7.8	1
5		429	B			1.2	1.3	1.3			1.2	1.2	1.2	1
6	16	412	A	1.3	1.3				1.3	2.0				2
7		412	B		1.3					1.5				2
8	20	349	A	1.0		2.0	2.3	2.5	1.3		3.7	7.0		1
9		349	B			1.5	1.4	1.4			1.4	1.5		1
10	25	282	A	1.5		1.9			2.0		4.4	9.0		1
11		282	B			1.4					1.6	1.4		1

Contributor: Swann, H. G.

References: [1] Schneider, E. C., and Clark, R. W., Am. J. Physiol. 75:298, 1926. [2] Rahn, H., and Otis, A. B., ibid 150:210, 1947.

116. EFFECT OF ACUTE EXPOSURE TO 2.43% O_2 ON PULMONARY FUNCTION: DOG

Death results in 8-20 minutes. Values are averages of 4 dogs for first five minutes of breathing time, and of 3 dogs thereafter.

	Breathing Time min	Respiratory Rate breaths/min	Ventilation Ratios: Experimental[1] / Control (at rest)	Ventilation Ratios: Experimental[2] / Control (at start)	Arterial Blood: O_2 Sat. %	Arterial Blood: pCO_2 mm Hg	Arterial Blood: pH
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	0[3]	16	1.5		93	44	7.32
2	1	32	8.3	5.5	32	23	7.54
3	2	34	6.9	4.6	21	23	7.53
4	5	21	4.0	2.7	17	14	7.47
5	9	19	2.8	1.9	14	14	7.37
6	Terminal[4]	0			12	26	7.16

/1/ Ratio of experimental ventilation to ventilation of healthy dog at rest. /2/ Ratio of experimental ventilation to ventilation of same dogs at start (minute before anoxia). /3/ Minute before anoxia. /4/ Observations taken a few seconds before cardiac failure.

Contributor: Swann, H. G.

Reference: Swann, H. G., and Brucer, M., Texas Repts. Biol. M. 7:539, 1949.

117. EFFECT OF PROGRESSIVE ANOXIA ON PULMONARY FUNCTION: DOG

Rebreathing through soda lime into a spirometer of 3.52 liter capacity; death resulting in 15-28 minutes. Values are averages of 4 dogs for first 14 minutes of breathing time, and of 3 dogs thereafter. In this type of anoxia, increase in ventilation is apparently due to increase in respiratory rate (compare Columns B and D).

	Breathing Time min	Respiratory Rate breaths/min	Ventilation Ratios: Experimental[1] / Control (at rest)	Ventilation Ratios: Experimental[2] / Control (at start)	Arterial Blood: O_2 Sat. %	Arterial Blood: pCO_2 mm Hg	Arterial Blood: pH
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	0[3]	22.8	2.2		87	39	7.31
2	3-5	25.2	2.9	1.1	74	41	7.31
3	8-9	42.0	5.6	1.8	62	32	7.41
4	12-14	30.8	5.0	1.4	36	24	7.42
5	17-19	26.4	3.7	1.2	25	18	7.47
6	22-23	17.2	3.5	0.8	20	16	7.37
7	Terminal[4]	0			11	23	7.14

/1/ Ratio of experimental ventilation to ventilation of healthy dog at rest. /2/ Ratio of experimental ventilation to ventilation of the group of 4 dogs during minute before anoxia. /3/ Minute before anoxia. /4/ Observations taken a few seconds before cardiac arrest.

Contributor: Swann, H. G.

Reference: Swann, H. G., and Brucer, M., Texas Repts. Biol. M. 7:553, 1949.

118. EFFECT OF HYPERVENTILATION ON BLOOD CO_2 CARRIAGE: MAN

Values are averages of 3 subjects, hyperventilated in a body respirator for 24 hours.

	Hyperventilation	Minute Volume L/min	Plasma: CO_2 Content vol %	Plasma: pH	Plasma: CO_2 Capacity[1] vol %
	(A)	(B)	(C)	(D)	(E)
1	Before	7.5	61.2	7.37	62.3
	During				
2	At 1 hr	17.7	52.3	7.48	62.6
3	At 12 hr	19.1	46.0	7.53	61.0
4	At 24 hr	18.9	44.6	7.50	58.6
	After				
5	At 1 hr	8.7	51.5	7.38	56.8
6	At 24 hr	7.0	53.5	7.38	58.1

/1/ At pCO_2 of 40 mm Hg.

Contributors: (a) Vandam, L. D., (b) Swann, H. G.

Reference: Brown, E. B., Campbell, G. S., Johnson, M. N., Hemingway, A., and Visscher, M. B., J. Appl. Physiol. 1:33, 1948.

119. EFFECT OF COMBINED ANOXIA AND HYPERCAPNIA ON ALVEOLAR CO_2 AND O_2: MAN

Part I: TABULAR

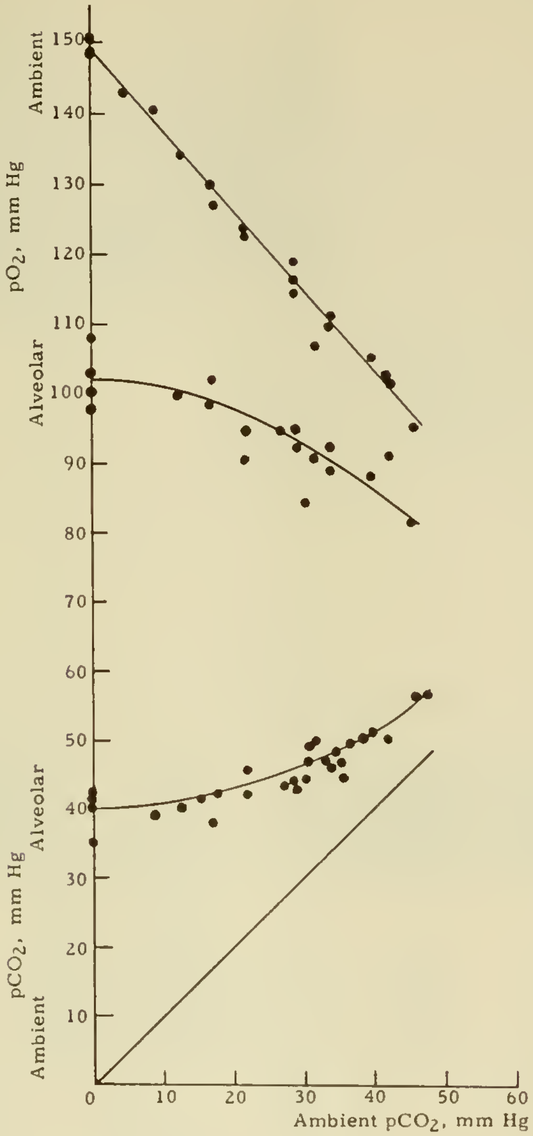
ΔpCO_2 = difference between ambient and alveolar pCO_2; ΔpO_2 = difference between ambient and alveolar pO_2.

	Subjects no.	Exposure Time min	Ambient Air				Alveolar Air				ΔpCO_2	ΔpO_2
			CO_2	O_2	pCO_2	pO_2	CO_2	O_2	pCO_2	pO_2		
			%		mm Hg		%		mm Hg		mm Hg	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
1	4	Rest	0.03	20.94	0.2	150.1	5.76	14.18	40.8	100.4	40.6	49.7
2		4	1.28	19.62	9.2	140.5	5.49	14.60	39.3	103.7	30.1	36.8
3		10	2.41	18.32	17.3	131.2	5.94	13.75	42.3	98.5	25.0	32.7
4		23	3.84	16.63	27.5	119.1	5.81	13.28	43.5	95.0	16.0	22.1
5		28	4.79	15.50	34.3	111.0	6.50	13.01	46.4	92.5	12.1	18.5
6		34	5.95	14.18	42.6	101.5	7.08	12.55	50.4	89.3	7.8	12.2
7	4	Rest	0.03	20.94	0.2	150.1	5.92	14.55	41.9	103.0	41.7	47.0
8		4	0.75	20.23	5.3	143.4	4.90	16.05	33.7	112.8	26.6	30.6
9		10	1.79	18.97	12.6	134.4	5.74	14.20	40.4	100.0	27.8	34.4
10		22	3.15	17.48	22.3	123.7	5.95	13.49	42.2	95.2	19.9	28.5
11		28	4.07	16.42	28.8	116.3	6.22	13.09	44.1	92.9	15.3	23.4
12		34	4.83	15.50	34.1	109.6	6.61	12.95	46.3	89.0	12.2	20.0
13		46	5.66	14.52	40.0	102.8	6.93	12.39	49.3	88.2	12.3	18.4
14		51	6.54	13.45	46.2	95.2	7.87	11.45	55.8	81.4	9.6	13.8
15	4	Rest	0.03	20.94	0.2	150.1	5.81	13.85	41.1	98.1	39.9	52.0
16		18	2.21	19.34	15.9	138.5	5.85	14.84	41.4	105.6	25.5	32.9
17		34	4.32	20.57	31.0	147.5	6.57	17.79	46.8	127.0	15.8	20.5
18		42	5.41	19.54	38.8	140.0	7.10	16.86	50.7	123.7	11.9	16.3
19		51	6.72	20.52	48.2	147.2	7.92	18.98	56.7	135.8	8.5	11.4
20	4	Rest	0.03	20.94	0.2	148.5	4.95	15.08	35.5	108.2	35.3	40.3
21		17.5	2.47	18.13	17.4	127.5	5.39	14.50	38.0	102.2	20.6	25.3
22		28	4.19	16.25	29.4	114.4	6.14	13.53	42.9	95.0	13.4	19.4
23		42	4.60	15.22	32.3	106.8	6.54	13.01	46.0	91.2	13.5	15.6
24		52	4.98	13.27	35.0	93.2	6.64	10.85	46.5	76.1	11.5	17.1
25		58	4.78	12.45	33.6	87.3	6.54	10.73	45.9	73.5	12.3	13.8
26		66	4.36	13.21	30.6	92.6	6.33	10.04	44.4	70.5	13.8	22.1
27		72	5.13	10.45	36.2	73.5	6.35	8.72	44.5	60.7	8.3	12.8
28	10	Rest	0.03	20.94	0.2	148.8	5.96	13.77	42.3	97.6	42.0	51.2
29	8	19	3.07	17.53	22.2	122.7	6.38	12.73	45.5	90.6	22.3	32.1
30	10	31	4.32	15.50	30.7	110.0	6.98	11.91	49.6	84.4	18.9	25.6
31	7	54	4.98	12.83	35.2	90.8	6.88	10.23	48.5	72.1	13.3	18.7

Contributors: (a) Behnke, A. R., (b) Swann, H. G.

Reference: Consolazio, W. V., Fisher, M. B., Pace, N., Pecora, L. J., Pitts, G. C., and Behnke, A. R., Am. J. Physiol. 151:479, 1947.

Part II: GRAPHIC



Contributors: (a) Behnke, A. R., (b) Swann, H. G.

Reference: Consolazio, W. V., Fisher, M. B., Pace, N., Pecora, L. J., Pitts, G. C., and Behnke, A. R., Am. J. Physiol. 151:479, 1947.

120. EFFECTS OF BREATHING CO_2

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

Part I: ON VENTILATION: MAMMALS

	Subjects no.	Exposure Time min	Method of Administration	CO_2 Concentration	Observed Change (% of Resting Value): Minute Volume %	Respiratory Rate %	Tidal Volume %	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
					Man				
1	28	1	Box bag	4% in air	20(1-39)			Maximum minute volume claimed in most cases.	1
2		2			55(20-120)				
3		3			68(34-190)				
4		4			78(56-300)				
5		5			84(56-370)				
6	23	1	Box bag	4% in air	16(1-30)			Subjects with emphysema.[1]	1
7		2			33(9-74)				
8		3			41(16-84)				
9		4			47(17-85)				
10		5			51(23-96)				
11	7	1	Box bag	4% in air	20(1-37)			Subjects with asthma.	1
12		2			59(40-83)				
13		3			67(47-98)				
14		4			77(53-102)				
15		5			95(70-126)				
16	42	2.5-8.5	Regulator, 10-liter reservoir and mask	7.6% in O_2	544(201-1178)	103(14-413)	269(51-448)	"Plateau" of not more than 10% variation in four 30-sec periods, shown by 27/42 and 13/31.	2
17	31			10.4% in O_2	857(402-1530)	150(43-531)	331(146-542)		
18	18	Up to 5	Spirometer	2% in 12% O_2	38.9(14-94)			Effects of hypoxia and hypercapnia are additive.	3
19				2% in 17% O_2	31.0(21-57)				
20				2% in 21% O_2	27.8(16-42)				
21	41	5	Special mask and plethysmograph	2% in air	60			Normal and premature infants.	4
22	45			2% in 15% O_2	50				
23	42			2% in 15% O_2[2]	50				
24	41			0.5% in 15% O_2[2]	3				
25	25	5	Box bag	4% in air	76(23-157)			Subjects with pneumoconiosis, grade III to grade V.	5
26					64(30-101)				
27					38.5(26-52)				
28	22	5-20	Spirometer and mouthpiece	5% in air	234(144-391)			Subjects followed "until ventilation became uniform."	6
29	8	8-10	Mouthpiece and demand valve	2.16% in air	36.1(32-40)	No significant change.	43.2(21.5-116)		7
30				4.31% in air	146(112-190)	20.6(-18 to +37)	106(83.5-190)		
31				5.48% in air	266(211-300)	34.0(22-53)	175(133-214)		
32	17	8-15	Tissot and Siebe-Gorman mask	1% in air	14.2(4-31)			Effects of O_2 and CO_2 additive.	8
33				1% in O_2	28.4(14-61)				
34	12			2% in air	34.3(18-44)				
35				2% in O_2	52.8(41-74)				
36	15			4% in air	98.6(63-146)				
37				4% in O_2	128.5(88-202)				
38	22	10	Special mask and plethysmograph	0.5%	12			Normal and premature infants.	4

39	7-12	10	Douglas bag	4% in air	110[3]			Normal subjects, and subjects with melancholia.	9
40				5.5% in air	190				
41				6.5% in air	315				
42	3	10		4% in air	75[4]; 78[5]			Subjects with depression and inhibition during illness and recovery.	9
43				5.5% in air	134[4]; 167[5]				
44				6.5% in air	264[4]; 283[5]				
45	6	13	Spirometer	3.3-7.8% in air	925(750-1150)[6]			Normal subjects.[7]	10
46	20				400(0-700)			Subjects with emphysema.	
47	22	14	Douglas bag	5% in O_2	130-200			Subjects with congenital heart disease.	11
48	6	15-20	Gasometer and anesthesia mask	26% in 10% O_2	75(54-104)			Subjects with anoxia.	12
49	13	20-25	Douglas bag	5-7% in O_2	332(90-750)			Normal subjects.[8]	13
50	35				145(42-298)			Subjects with emphysema.	
51	12	20-30	Gas tank and anesthesia bag	3-5% in air	202[9]; 329[10]			Normal subjects.	14
52	9				144[9]; 192[10]			Subjects with emphysema.	
53	3				131[9]; 278[10]			Subjects with cyanotic heart disease.	
54	3				115[9]; 315[10]			Subjects with chronic acidosis.	
55	2				65[9]; 181[10]			Subjects with chronic alkalosis.	
56	3	25-30	Gas tank and anesthesia bag	3-5% in air	85.6[9]; 375[10]			1.8-2.4 g salicylate given 1.5-2 hr before test.	15
57	9	30	Douglas bag	5% in O_2	130-200		87-110	Early peak of hyperventilation disappears as subjects become familiar with tests.	11
58		18 hr	Exposure chamber	3.8-4.5% in air	200			No evidence of secondary decrease of ventilation over this period.	16
59	2	78 hr	Exposure chamber	0% in air	-12[3,11]		Alveolar CO_2 elevated 18% with 3% CO_2. Maximum alveolar pCO_2 reached in 8-13 hr.		17
60				3% in air	88[3,12]; 84[3,11]				
61				5.66% in air	429[3,12]; 368[3,11]				
62	3	5-8 da	Exposure chamber	1-5% in air	47(24-60)				18
63					33(14-51)				
					Cat				
64	56	5	Douglas bag	35-50% in air and O_2		Apneustic and gasping pattern of respiration rapidly produced.		Chloralose anesthesia.	19

/1/ Extension of exposure to 12-14 min in 9 cases resulted in more normal hyperventilation. /2/ Preceded by inspiration of O_2 for 5 min. /3/ Approximate figure from graph. /4/ Illness. /5/ Recovery. /6/ Maximum response. /7/ Response reduced by airway obstruction. /8/ Results compared with controls breathing O_2. /9/ 3% CO_2 in air. /10/ 5% CO_2 in air. /11/ Acclimatized. /12/ Unacclimatized.

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

Part I: ON VENTILATION: MAMMALS (Concluded)

	Subjects no.	Exposure Time min	Method of Administration	CO_2 Concentration	Observed Change (% of Resting Value) Minute Volume %	Respiratory Rate %	Tidal Volume %	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Dog								
65	32	5	Demand valve	6.5% in O_2 or 5.1% in air			Blocking of chemoreceptor has no effect on CO_2 hyperventilation, breathing O_2; slight decrease breathing air.	Chloralose, with and without chemoreceptor block.	20
66	9		Gas bag and tracheal cannula	5% in air	69[13]; 42[14]	24[13]; 16[14]	20[13]; 19[14]	Normal and vagotomized dogs.	21
67				10% in air	131[13]; 50[14]	33[13]; 12[14]	39[13]; 38[14]		
68				20% in air	123[13]; 35[14]	39[13]; -2[14]	64[13]; 62[14]		
69				40% in air		46[13]	104[13]; 92[14]		
70				80% in air		52[13]	122[13]; 106[14]		
	Guinea Pig								
71	20	9-13 da	Exposure chamber	3-15%		Increase in frequency becomes slower. Apneustic respiration appears at 8th da. Gasping, deep respiration for 3 da.			22
	Hamster and Squirrel								
72	6[15]	20	Cylinder gas mixture (humidified)	3-10% in O_2		5% CO_2 increases respiratory rate 180%.		Hibernating animals.	23
	Hedgehog								
73	8	70-240		3% in O_2		No change[13, 16]		Normal and hibernating animals.	24
74				6% in O_2		10[13]; 60[16]			
75				9.5%		10[13]; 35[16]			

/13/ Normal. /14/ Vagotomized. /15/ 4 hamsters and 2 squirrels. /16/ Hibernating.

Contributor: Shephard, R. J.

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Part II: ON BLOOD GASES AND ALVEOLAR CO_2 THRESHOLD: MAN

A = arterial, V = venous.

	Subjects no.	Exposure Time min	Method of Administration	CO_2 Concentration	Blood	Observed Change (% of Resting Value): CO_2 Content %	O_2 Content %	pH %	pCO_2 %	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
	Blood Gases										
1	4	1	BLB mask	5% in air	A	4.4-4.6		-0.5 to -0.8		Samples obtained from pulmonary veins at cardiac catheterization.	1
2	12	5-15	Mask	5% in 21% O_2	A	5.9(1.8-18.2)		-0.82(-1.22 to 0)	16.2(8-41)	Normal subjects.	2
3					V	1.7(-1.1 to +8.5)		-0.55(-1.35 to 0)	18.4(3.5-42)		
4	9				A	4.6		-0.55	15.2	Subjects with arteriosclerosis.	
5					V	2.0		-0.41	14.8		
6	6				A	6.7		-0.81	20.0	Subjects with essential hypertension.	
7					V	1.1		-0.41	10.2		
8	10				A	7.3		-1.08	26.4	Subjects with arteriosclerosis and hypertension.	
9					V	1.7		-0.82	14.6		
10	6	15-30		5% in air	A	5.4-8.3		-0.58 to -1.22	16.6-31.1		3
11					V[1]	1.2-1.6	17-25	-0.22 to -0.62	3.6-13.6		
12	13	20-25	Douglas bag	5% in O_2	A			-1.27(-0.68 to -1.89)	30.5(14-55)	Normal subjects.	4
13	35				A			-0.95(-0.27 to -2.06)	20.8(7.3-51.2)	Emphysematous subjects.[2]	
14	12	20-35	Gas tank and anesthesia bag.	3% in air	A			-0.13(-0.13 to -0.54)	6.0(2.5-11.2)	Normal subjects.	5
15				5% in air	A			-0.54(-0.27 to -1.08)	12.1(5.9-24.4)		
16	9			3%	A			-0.54(-0.13 to -0.81)	10.2(6-16)	Subjects with emphysema, stages III to V.[3]	
17				5%	A			-0.68(-0.41 to -1.22)	19.2(12-29)		
18	3			3%	A			-0.40	7.0	Subjects with cyanotic heart disease.	
19				5%	A			-0.81	12.6		
20				3%	A			-0.10	1.2	Subjects with chronic acidosis.	
21	1			5%	A			-0.81	4.0		
22	2			3%	A			-0.26	3.4	Subjects with chronic alkalosis.[4]	
23				5%	A			-0.65	6.9		
24	3	20-35		3% in air	A			-0.10	2.0	1.8-2.4 g salicylate 1.5-2 hr before test.[5]	6
25				5% in air	A			-0.36	11.2		
	Alveolar CO_2 Threshold and Sensitivity										
26	5	5-10	Spirometer	10% in O_2	A	7.4	4.9			Epileptic subjects.	7
27					V	3.2	40.4				
28	4			4-8% in air	A	2.1	3.1				
29					V	-2.5	21.8				

/1/ Internal jugular. /2/ Results compared with previous values for patients breathing O_2. /3/ Sensitivity of respiratory center, -60 to -90%. /4/ Sensitivity of respiratory center, -70%. /5/ Estimated sensitivity of respiratory center doubled.

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

Part II: ON BLOOD GASES AND ALVEOLAR CO_2 THRESHOLD: MAN (Concluded)
A = arterial, V = venous.

	Subjects no.	Exposure Time min	Method of Administration	CO_2 Concentration	Blood	Observed Change (% of Resting Value) CO_2 Content %	O_2 Content %	pH %	pCO_2 %	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Alveolar CO_2 Threshold (concluded)					
30	4	5-10	Spirometer	4-6% in 8-12% O_2	A	-0.4	-1.2			Epileptic subjects.	7
31					V	No change	0.9				
32	8	7	Pressure chamber	2% in O_2	A	13.3	-0.4	-1.89	57	3-5 atmospheres pressure.[6]	8
33					V	3.8	21.9	-1.09			
34	8	8-10		2.16% in air	A	3.1(0.8-6.1)	2.4(1.0-3.7)	-0.63(-0.38 to -0.90)	14.8(8.1-21.7)		9
35					V	0.4(0.1-0.6)	14.0(4.8-24.1)	-0.39(-0.18 to -0.59)	7.3(3.1-10.9)		
36	4	15-20		2.5%	A			-0.67	10.6	Convalescent hospital patients.	10
37					V			-0.67	7.4		
38	8			3.5% in air	A			-0.68(-1.09 to -0.13)	13.4(2.3-28.6)		
39					V			-0.41(-0.82 to -0.13)	10.2(2.2-21.3)		

/6/ Results compared with previous experiments of subjects breathing O_2 at 3.5 atmospheres.

Contributor: Shephard, R. J.

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Part III: ON OTHER RESPIRATORY VARIABLES: MAMMALS

	Animal	Subjects no.	Exposure Time min	Method of Administration	CO_2 Concentration	Effect on Variable	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
						Alveolar CO_2 Concentration[1]		
1	Man	2	0-1	BLB mask	5% in air	13-21%		1
2					5% in O_2	16-22%		
3			1-5		5% in air	9-17%		
4					5% in O_2	3-10%		
5		1	1.5	Exposure chamber	3.48% in air	11.8%		2
6			5			8.9%		
7		5	10		5.53-5.96% in 20-60% O_2	24(14.8-31.5)%		a
8		3	5-8 da		1-5% in air	9.2(1-14)%[2]		3
9						6.4(-3 to +11.1)%[3]		
						O_2 Consumption during Hypercapnia[4]		
10	Man		0-2 and 10-15			2.1 ml/L	Continuous analysis of expired gas by Rein method; events of first 2 min analyzed.	4
11		3	0-1	Douglas bag	5% in air	31.8(10-54)%[1]	Allowance for effects due to change of cardiac output and O_2 stores.	5
12			1-5			0.9-1.2 ml/L; 3.6(-4 to +9)%[1]		
13			10-15	Douglas bag	2-5%	0.6-2.5 ml/L	"Steady state" measurements.	6

14		1	30	Added dead space		0.3-0.7 ml/L	Optimal depth and frequency for respiratory work; higher values outside this range.	7
15		2	30	Spirometer	4.5% in air	3.8 ml/L; 16%[1]		8
16		4	Up to 40	Douglas bag	0-9% in air	1.4 ml/L		9
17			40	Cylinder gas mixture	5-7% in air	0.5 ml/L	"Steady state" measurements.	10
						Brain O_2 Tension[1]		
18	Man	4	7	Pressure chamber	2% in O_2	100% compared with O_2 at 3.5 atmospheres.	Experiments at 3.5 atmospheres on schizophrenic patients.	11
						Vital Capacity		
19	Man	2	2-5	BLB mask	5% in O_2	3% increase in one subject; no change in other.		5
						End-Tidal Position		
20	Man	13	4	Whole body plethysmograph and spirometer	2-4% in air	No change.		12
21		2	5	BLB mask	5% in O_2	Expiratory shift of 40 ml, 80 ml.[5]	Chest stethograph.	5
22	Cat	12		Rebreathing	4.8% and 6.9% in 25% O_2	Slight increase of expiratory tonus.	Dial anesthesia; whole body plethysmograph.	13
23	Dog	9		Rubber bags and tracheal cannula	0-20% in air	Changes small, probably insignificant.	Urethane anesthesia; inspiratory shift during hypercapnia after vagotomy.	14
24	Rabbits and cats		1-3	Spirometer and tracheal cannula	2-10% in air	No consistent change.	Urethane anesthesia; whole body plethysmograph.	15
						Total Body Accretion of CO_2 and Steady State		
25	Man	31	14-30	Douglas bag	5% in O_2	1000-2000 ml	9 normal subjects, and 22 with congenital heart disease.[6]	1
26		25	20-35	Gas tank and anesthetic bag	3-5% in air	Steady state in 20-30 min.	Normal, and emphysematous subjects.	16
27		2	30	Spirometer	4.5% in air	390-4900 ml[7]	Steady state not reached in 30 min.	8
28			18 hr	Exposure chamber	5.8%	Steady ventilation in 20-30 min.		17
29	Dog	2	45	Cylinder gas mixture	3.45% in air	38 ml/kg body wt.	Pentothal anesthesia, controlled respiration.	18
30	Rat		6-28 da	Exposure chamber	10% in 20-35% O_2	68 ml in 200 g rat.	Data combined for different parts of various rats.[8]	19
						CO_2 Capacity of Lung Tissues		
31	Dog	13	0.5-1.0	Tracheal cannula	0-17%	2.6 ml/mm Hg pCO_2	Exsanguinated lung.	20
						Survival Time[8]		
32	Mouse	138	Up to 90	Exposure chamber	32.5% in O_2	90		21
33					40% in O_2	62		
34					47.5% in O_2	52		
35					55% in O_2	20		
36					62.5% in O_2	16		
37					70% in O_2	10		
38					77.5% in O_2	4		
39		140			40% in 4.7% O_2	1		
40					40% in 6.5% O_2	5		

/1/ % increase or decrease. /2/ Short term. /3/ Long term. /4/ Extraventilation. /5/ 1.0-1.6% increase. /6/ Extraventilation/accretion ratio steady at 30 min, CO_2 still accumulating. /7/ 40 to 700 ml/mm Hg pCO_2. /8/ In minutes.

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

Part III: ON OTHER RESPIRATORY VARIABLES: MAMMALS (Concluded)

	Animal	Subjects no.	Exposure Time min	Method of Administration	CO_2 Concentration	Effect on Variable	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
						Survival Time[8] (concluded)		
41	Mouse	140	Up to 90	Exposure chamber	40% in 12% O_2	128		21
42	(concl'd)				40% in 20% O_2	95		
43					40% in 60% O_2	70		
44					40% in 380% O_2	60		
45					40% in 800% O_2	30		

/8/ In minutes.

Contributor: Shephard, R. J.

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121. EFFECTS OF BREATHING O_2

All controls breathing air, unless otherwise specified. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

Part I: ON VENTILATION: MAMMALS

	Subjects no.	Exposure Time min	Method of Administration	O_2 Concentration	Observed Change (% of Resting Value) Minute Volume %	Respiratory Rate %	Tidal Volume %	Special Conditions	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
					Man				
1	33	1-2	Facepiece and demand valve	100%	-3.1(-22 to +23)				1
2	20	1	Special mask	100%	-15.8	-9.5	-6.3	Premature infants.	2
3		2			0				
4		1			-34.6	-27.7		Premature infants, preceding hypoxia.	
5		2			0				
6	31	1			-25.0		-18.0	Normal infants, preceding hypoxia.	
7		2			0				
8	36	1	Special mask	60%	-11	-0.6	-8.7	Newborn infants.	3
9		2			0	12.4	-11.3		
10		1		100%	-12	3.6	-16.0		
11		2			3	5.2	-2.0		
12	20	3	Special mask	100%	11.2			Premature infants.	2
13		4			16.0				
14		5			13.5				
15		3, 4, 5			15.8-25.0	Almost entirely change of rate.		Premature infants, preceding hypoxia.	
16	36	3	Special mask	60%	3	13.6	-5.3	Newborn infants.	3
17		4			11	13.9	-0.7		
18		5			5	13.6	-4.7		
19		3		100%	14	11.0	4.0		
20		4			11	12.8	2.0		
21		5			5	8.5	-2.0		
22	31	3	Special mask	100%	44.6			Normal infants, preceding hypoxia.	2
23		4			36.8				
24		5			25.2				
25	33	6-8	Facepiece and demand valve	100%	7.6(-29 to +39)[1]	14.3(-24 to +24)[2]			1
26	5	10	Douglas bag	100%	18	No significant change.	18	Normal.	4
27	6				32		32	Pregnant.	
28	4	10-20	Rotometers and reservoir	33%	-8(-5 to -14)[3]			Severe muscular work.	5
29				66%	-13(-2 to -28)				
30				100%	-15(-11 to -23)				
31	1	12-14	Douglas bag	100%	-35[4]			Severe muscular work.	6
32	33	15-20	Tissot spirometer	100%	13.6(-8 to +33)				7
33	7	15-20	Anesthesia mask	100%	16.0(4-35)				8
34	9	15-30		100%	16.4(8.5-29.8)			Anemia.[5] Control breathing unspecified.	9

/1/ Assuming normal minute volume = 7.9 L/min. /2/ Assuming normal respiratory rate = 14 breaths/min. /3/ Approximate figures from graphs. /4/ At O_2 consumption of 3 L/min. /5/ Four patients showed less hyperventilation as hemoglobin level increased.

121. EFFECTS OF BREATHING O_2 (Continued)

All controls breathing air, unless otherwise specified. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

Part 1: ON VENTILATION: MAMMALS (Concluded)

	Subjects no.	Exposure Time min	Method of Administration	O_2 Concentration	Observed Change (% of Resting Value) Minute Volume %	Observed Change (% of Resting Value) Respiratory Rate %	Observed Change (% of Resting Value) Tidal Volume %	Special Conditions	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Man (concluded)								
35	8	15	Douglas bag and compression chamber	350%[6]	23.4	-6.3	33.8		10
36		30			42.0	14.8	20.2		
37	10	20-30	Oxygen tent	42-74%	30(-15 to +134)		17.6(-20.4 to +75)	Newborn infants[7]. Discontinuous readings; neck seal plethysmograph.	11
38	15	20-30	Spirometer	100%	15.4	11.9	2.9		12
39	6	30	Spirometer	100%	5.5				13
40	2	30	BLB mask[8]	100%[9]	14.2	9.7	1.8		14
41	13	30	BLB mask[8]	100%[9]	13.6			Acyanotic congenital heart disease.	14
42	14				5.4			Cyanotic congenital heart disease.	
43	13	30-40	Douglas bag	100%	7.4(-10 to +36)			Normal.	15
44	35				-5.3(-28 to +24)			Emphysema.	
45		Up to 90		100%	20.0			Alveolar pCO_2 also lowered.	16
46	10	80-240	Mask and spirometer	96-99%	Pneumograph records; hyperpnea in only 1 subject.	Increase in 1 subject during 4th hr.		Control breathing unspecified.	17
	Cat and Dog								
47	13[10]	1-4	Rubber bag	100%	Decrease towards end of test; return to normal.	Reduction of frequency and amplitude.		Chloralose; body plethysmograph.	18
	Dog								
48	7	1	Douglas bag	100%[11]	-31 to -11			Effect abolished by denervation of carotid and aortic bodies.	19
49	283	10		100%	-18.2[12] -13.6[13] 8.0[14] 2.0[15]			Varying periods of chloral anesthesia.	20
	Rabbit								
50	4	0.5-1		100%	Decrease.	Typical reduction of respiratory amplitude and rate.		Urethane anesthesia.	21

/6/ Pressure greater than 1 atmosphere. /7/ Controls not breathing air. /8/ Boothby, Lovelace, Bulbulian mask. /9/ Alveolar pO_2 greater than 80%. /10/ 12 cats, 1 dog. /11/ Arterial pO_2 greater than 100 mm. /12/ Anesthesia for 30-60 min. /13/ Anesthesia for 60-90 min. /14/ Anesthesia for 90-150 min. /15/ Anesthesia for 150-300 min.

Contributor: Shephard, R. J.

References: [1] Dripps, R. D., and Comroe, J. H., Am. J. Physiol. 149:277, 1947. [2] Cross, K. W., and Oppé, T. E., J. Physiol., Lond. 117:38, 1952. [3] Cross, K. W., and Warner, P., ibid 114:283, 1951. [4] Loeschcke, H. H., Pflügers Arch. 251:211, 1949. [5] Bannister, R. G., and Cunningham, D. J., J. Physiol., Lond. 125:118, 1954. [6] Asmussen, E., and Nielsen, M., Acta physiol. scand. 12:171, 1946. [7] Shock, N. W., and Soley, M. H., Proc. Soc. Exp. Biol. 44:418, 1940. [8] Keys, A., Stapp, J. P., and Violante, A., Am. J. Physiol. 138:763, 1943. [9] Chiodi, H., Fasciolo, J. C., Suárez, J. R., and Taquini, A. C., J. Appl. Physiol. 1:148, 1948. [10] Lambertsen, C. J., Kough, R. H., Cooper, D. V., Emmel, G. L., Loeschcke, H. H., and Schmidt, C. F., ibid 5:471, 487, 803, 1952. [11] Howard, P. J., and Bauer, A. R., Am. J. Dis. Child. 79:611, 1950. [12] Alveryd, A., and Brody, S., Acta physiol. scand. 15:140, 1948. [13] Otis, A. B., Rahn, H., Brontman, M., Mullins, L. J., and Fenn, W. O., J. Clin. Invest. 25:413, 1946. [14] Shephard, R. J., J. Physiol., Lond. 127:498, 1955. [15] Prime, F. J., and Westlake, E. K., Clin. Sc., Lond. 13:321, 1954. [16] Edelmann, A. W., Whitehorn, W. V., and Hitchcock, F. A., Fed. Proc. 4:18, 1945. [17] Behnke, A. R., Fenimore, S. J., Poppen, J. R., and Motley, E. P., Am. J. Physiol. 110:565, 1935. [18] Von Euler, U. S., and Liljestrand, G., Acta physiol. scand. 4:34, 1942. [19] Watt, J. G., Dumke, P. R., and Comroe, J. H., Am. J. Physiol. 138:610, 1943. [20] Binet, L., and Strumza, M. V., C. rend. Soc. biol. 141:3, 1947. [21] Hejneman, E., Acta physiol. scand. 6:333, 1943.

Part II: ON OTHER RESPIRATORY VARIABLES: MAN

Subjects no.	Exposure Time min	Method of Administration	O_2 Concentration	Arterial Blood	Special Conditions	Reference
(A)	(B)	(C)	(D)	(E)	(F)	(G)
				Arterial Blood		
6	15-30		85-100%	No change observed in CO_2 content, pCO_2, or pH.		1
8	60	Mouthpiece and demand valve	100%	O_2 content = 10.5 CO_2 content = -1.4 pCO_2 = -5.0 Hb saturation = 3.7 pH = 0.13	Some experiments at pressure of 3.5 atmospheres.	2
			350%	O_2 content = 39.1 CO_2 content = -6.2 pO_2 = 2000 pCO_2 = -12.8 Hb Saturation = 3.9 pH = 0.4		
28	1440	Demand mask[2]	100%	No change in CO_2 content, pCO_2, or pH.		3
				Cerebral Venous Blood		
8	60	Mouthpiece and demand valve	100%	O_2 content = 4.7 CO_2 content = 0.5 pO_2 = 8.1 pCO_2 = 2.0 Hb saturation = 4.6 pH = no change	Some experiments at pressure of 3.5 atmospheres.	2

/1/ Change observed; % increase or decrease from resting value. /2/ Alveolar pO_2 mask checks.

121. EFFECTS OF BREATHING O_2 (Concluded)

All controls breathing air, unless otherwise specified. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

Part II: ON OTHER RESPIRATORY VARIABLES: MAN (Concluded)

	Subjects no.	Exposure Time min	Method of Administration	O_2 Concentration	Effect on Variable[1]	Special Conditions	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
					Cerebral Venous Blood (concluded)		
20	8	60	Mouthpiece and demand valve	350%	O_2 content = 39.6	Some experiments at pressure of 3.5 atmospheres.	2
21					CO_2 content = -0.9		
22					pO_2 = 97.0		
23					pCO_2 = 6.0		
24					Hb saturation = 37.0		
25					pH = -4.1		
					Alveolar CO_2 Pressure		
26	2	5	Douglas bag	100%	-3.4		4
27	4	10-20	Rotometers and reservoir	33%	2[3]	Heavy exercise.	5
28				66%	5[3]		
29				100%	10[3]		
30	1	12-14	Douglas bag	100%	25[4]	Heavy exercise.	6
31	2	30	BLB mask[5]	100%[6]	-11.2		7
32	2	660	Decompression chamber	90%	-25	Decrease occurs mainly during first 2 hr.	8
					O_2 Consumption		
33		15-30	Spirometer	90%	No change.		9
34	4	20-240	Helmet	97%	14-24[7]	Large correction for N_2 elimination from 0-20 min. Control breathing unspecified.	10
35	2	30	BLB mask[5]	100%[6]	No change in one subject, 8% increase in other.		7
36	2	168 hr	O_2 chamber	45%	No change.		11
					Vital Capacity		
37	12	30-40	Spirometer	100%	-3.0(-6.9 to +7.5)		12
38	80	24 hr	Mask and demand valve	50-100%	Decreases 0-1480 ml; mainly 200-300 ml.	Complaints of substernal distress after 14 hr with 75% and 100%. Not seen in controls breathing air.	3
39	2	65 hr	Decompression chamber	90%	5% decrease in one subject and 30% decrease in other.	Control breathing unspecified.	8

/1/ Change observed; % increase or decrease from resting value. /3/ Approximate figure from graph. /4/ At O_2 consumption of 3 L/min. /5/ Boothby, Lovelace, Bulbulian mask. /6/ Alveolar pO_2 greater than 80%. /7/ For first 20 min; subsequent return to normal.

Contributor: Shephard, R. J.

References: [1] Kety, S. S., and Schmidt, C. F., J. Clin. Invest. 27:484, 1948. [2] Lambertsen, C. J., Kough, R. H., Cooper, D. V., Emmel, G. L., Loeschcke, H. H., and Schmidt, C. F., J. Appl. Physiol. 5:471, 487, 803, 1952. [3] Comroe, J. H., Dripps, R. D., Dumke, P. R., and Deming, M., J. Am. M. Ass. 128:710, 1945. [4] Dautrebande, L., and Haldane, J. S., J. Physiol., Lond. 55:296, 1921. [5] Bannister, R. G., and Cunningham, D. J., ibid 125:118, 1954. [6] Asmussen, E., and Nielsen, M., Acta physiol. scand. 12:171, 1946. [7] Shephard, R. J., J. Physiol., Lond. 127:498, 1955. [8] Becker-Freysung, H., and Clamann, H. G., Klin. Wschr. 18:1382, 1939. [9] Benedict, F. G., and Higgins, H. L., Am. J. Physiol. 28:1, 1911. [10] Behnke, A. R., Fenimore, S. J., Poppen, J. R., and Motley, E. P., ibid 110:565, 1935. [11] Richards, D. W., and Barach, A. L., Quart. J. M. 3:437, 1934. [12] Alveryd, A., and Brody, S., Acta physiol. scand. 15:140, 1948.

122. PULMONARY N_2 WASHOUT: MAN

Nitrogen reduction, by inhalation of O_2 at constant tidal volume, can be measured by following continuously the N_2 concentration of respired gas with a nitrogen meter.

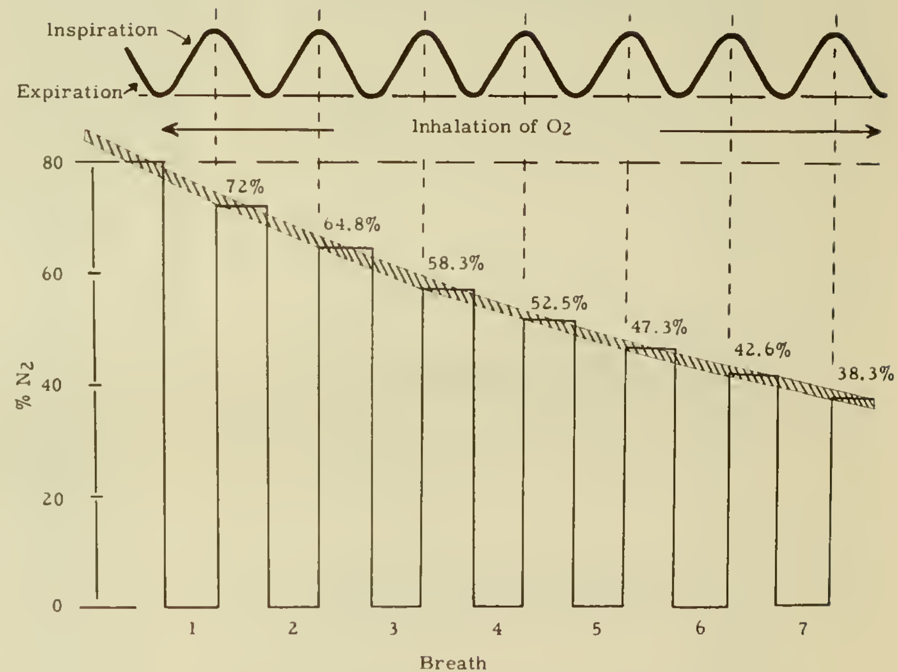
Part I: TABULAR

Alveolar gas at each breath is diluted 10%.

	Breath	% Alveolar N_2 at Beginning of Each Inspiration	Resulting Decrease in % Alveolar N_2 in Each Breath	% Alveolar N_2 at End of Each Inspiration
	(A)	(B)	(C)	(D)
1	1st	80	10 x 80 = 8.0	80 - 8.0 = 72
2	2nd	72	10 x 72 = 7.2	72 - 7.2 = 64.8
3	3rd	64.8	10 x 64.8 = 6.48	64.8 - 6.48 = 58.3
4	4th	58.3	10 x 58.3 = 5.83	58.3 - 5.83 = 52.5
5	5th	52.5	10 x 52.5 = 5.25	52.5 - 5.25 = 47.3
6	6th	47.3	10 x 47.3 = 4.73	47.3 - 4.73 = 42.6
7	7th	42.6	10 x 42.6 = 4.26	42.6 - 4.26 = 38.3

Part II: GRAPHIC

Each plateau represents the N_2 concentration of expired alveolar gas. The resulting washout curve is a single exponential curve, assuming the lungs function as a perfect mixing chamber and are washed out evenly.



Reference: Comroe, J. H., Jr., Forster, R. E., II, DuBois, A. B., Briscoe, W. A., and Carlsen, E., "The Lung," Chicago: The Year Book Publishers, Inc., 1956.

123. EFFECT OF BREATHING O_2 AT 3-4

Venous blood from internal jugular vein. C = control period of air breathing at one

	Inspired O_2 Pressure atm		O_2 Content vol %				Dissolved O_2 vol %		Hb Saturation %		O_2 Pressure mm Hg	
			C	E	C	E	C	E	C	E	C	E
	C	E	Arterial		Venous		Arterial		Venous		Venous	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
1	0.2	4.0	19.6	27.4	12.5	18.1	0.3	8.1	64.0	92.0		
2	0.2	4.0	18.3	25.8	11.4	18.0	0.3	6.8	63.4	92.9	36	82
3	0.2	4.0	18.0	25.2	9.4	19.0	0.3	6.4	51.3	100.0	27	100
4	0.2	3.5	18.9	26.1	10.2	19.0	0.3	6.2	54.5	93.6	32	85
5	0.2	3.5	18.2	25.5	12.3	18.0	0.3	6.5	64.2	89.7	35	79
6	0.2	3.5	19.3	25.6	11.7	17.5	0.3	6.6	61.0	90.8	35	72
7	0.2	3.5	16.5	23.9	9.4	12.0	0.3	6.4	56.9	67.6	36	41
8	0.2	3.5	18.0	24.8	11.5	17.0	0.3	6.0	62.1	88.7	37	70
9	0.2	3.5	19.1	26.5	12.9	18.0	0.3	6.6	64.6	88.5	38	66
10	0.2	3.5	18.6	25.7	13.0	17.4	0.3	7.2	69.3	89.1	40	64
11	0.2	3.5	18.7	25.7	13.7	18.4	0.3	6.6	73.2	96.0	42	97
12	0.2	3.5	18.2	25.7	13.2	18.4	0.3	5.6	65.1	89.7	36	67
13	0.2	3.5	18.9	26.4	12.9	19.6	0.3	6.5	64.7	96.8	36	100
14	0.2	3.5	20.7	28.5	14.5	18.5	0.3	6.9	66.8	84.5	39	58
15	0.2	3.5	19.5	27.3	16.4	20.2	0.3	6.8	79.9	96.7	50	100
16	0.2	3.4	17.9	25.7	12.0	16.7	0.3	6.6	66.8	86.4	38	61
17	0.2	3.0	20.5	26.8	13.6	17.8	0.3	5.7	63.9	84.3	37	59

Contributor: Behnke, A. R.

Reference: Lambertsen, C. J., Kough, R. H., Cooper, D. Y., Emmel, G. L., Loeschcke, H. H., Schmidt, C. F.,

124. EFFECT OF BREATHING AIR AT ONE ATMOSPHERE

Venous blood withdrawn from right

	Gas	Pressure atm	Exposure Time min	O_2 Content		O_2 Capacity		CO_2 Content		CO_2 Capacity[1]	
				Arterial vol %	Venous vol %	Arterial vol %	Difference vol %	Arterial vol %	Venous vol %	Arterial vol %	Difference vol %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
1	Air	1	132			19.6				42.5	
2	O_2	3.00	132	25.6	20.4	20.5	+0.89	45.9	51.7	43.9	+1.4
3	Air	1	100	20.5	12.1	20.3		44.3	49.1	41.0	
4	O_2	3.84	100	26.1	20.5	19.6	-0.76	42.3	48.5	40.0	-1.0
5	Air	1	64			23.1				40.2	
6	O_2	3.36	64	28.9	21.6	23.0	-0.03	39.9	44.3	40.2	0.0
7	Air	1	67	19.0	14.3	19.1		42.4	45.5	43.8	
8	O_2	3.92	67	25.1	20.1	18.4		42.5	47.0	45.0	+1.2
9	Air	1	193	21.7	16.7	23.5		45.3	48.6	41.5	
10	O_2	3.84	193	30.9	25.6	24.4	+1.11	38.8	41.7	41.0	-0.5
11	Air	1	92	21.3	15.8	23.8		51.7	55.2	44.2	
12	O_2	3.89	92	31.9	24.5	25.4	+1.64	50.9	55.5	44.2	0.0
13	Air	1	119	23.7	19.6	25.8		32.9	37.6	39.5	
14	O_2	3.88	119	31.5	24.6	24.6	-1.17	39.1	46.3	39.2	-0.3
15	Air	1	62	20.3	18.9	22.4		45.0	46.6	44.25	
16	O_2	3.89	62	29.3	25.9	22.8	+0.33	44.0	46.6	44.25	0.0
17	Air	1	165	18.9	13.6	20.8		43.9	46.2	43.0	
18	O_2	3.88	165	24.6	16.2	20.8	-0.02	41.4	48.6	43.5	+0.5

/1/ At 40 mm Hg. /2/ To calculate arterial volume, convert pO_2 values from mm Hg to atmospheres and multiply

Contributor: Behnke, A. R.

Reference: Behnke, A. R., Shaw, L. A., Shilling, C. W., Thomson, R. M., and Messer, A. C., Am. J. Physiol.

ATMOSPHERES ON BLOOD GASES: MAN

atmosphere, E = experimental period of O_2 breathing at increased ambient pressure.

CO_2 Content vol %				CO_2 Pressure mm Hg				pH				
C	E	C	E	C	E	C	E	C	E	C	E	
Arterial		Venous		Arterial		Venous		Arterial		Venous		
(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	(U)	(V)	(W)	(X)	
50.8	46.3	57.0	55.7									1
46.1	42.1	51.4	50.0	38	32	48	50	7.36	7.40	7.31	7.28	2
46.9	48.0	55.3	55.3	35	35	42	52	7.45	7.42	7.40	7.31	3
46.2	47.2	54.6	53.2	32	37	45	52	7.45	7.40	7.37	7.30	4
51.8	50.7	57.0	57.4	39	38	50	55	7.41	7.42	7.34	7.31	5
52.6	50.1	59.8	58.8	40	36	53	58	7.41	7.43	7.34	7.29	6
52.1	45.7	57.1	56.3	43	33	53	56	7.36	7.42	7.30	7.28	7
49.5	45.4	55.5	54.2	43	36	53	60	7.35	7.39	7.30	7.24	8
48.6	45.5	54.8	54.5	38	33	52	53	7.40	7.43	7.31	7.30	9
49.1	44.0	54.4	53.5	38	29	48	46	7.40	7.47	7.34	7.35	10
50.2	47.4	55.4	55.0	38	32	47	49	7.41	7.46	7.36	7.34	11
48.2	46.0	53.0	53.2	37	32	45	50	7.40	7.45	7.36	7.32	12
53.0	49.5	59.2	56.9	42	39	52	55	7.40	7.40	7.35	7.31	13
48.7	43.9	54.7	54.6	40	33	53	54	7.38	7.43	7.31	7.30	14
49.7	47.4	53.0	54.5	40	35	47	51	7.39	7.43	7.34	7.32	15
51.1	48.1	57.4	56.6	39	35	49	54	7.40	7.43	7.35	7.31	16
48.4	44.8	54.6	53.6	40	36	49	57	7.38	7.39	7.34	7.26	17

J. Appl. Physiol. 5:471, 1953.

AND O_2 AT 3-3.92 ATMOSPHERES ON BLOOD GASES: DOG

ventricle via jugular vein cannula.

O_2 in Physical Solution						pCO_2		pH		
Arterial				Venous						
Observed vol %	Calculated[2] vol %	Difference vol %	pO_2 mm Hg	Observed vol %	pO_2 mm Hg	Arterial mm Hg	Venous mm Hg	Arterial	Venous	
(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	(U)	
										1
5.47	5.61	-0.14	2190	0.36	130	44.5	59.7	7.35	7.26	2
						47.0	54.0	7.33	7.30	3
6.95	7.07	-0.12	2827	1.39	555	45.0	60.0	7.35	7.28	4
										5
6.29	6.16	+0.13	2462		80	39.0	48.0	7.36	7.31	6
						37.0	41.0	7.40	7.37	7
7.18	7.22	-0.04	2888	2.22	880	34.0	45.0	7.43	7.34	8
						48.0	51.0	7.32	7.31	9
6.90	7.07	-0.17	2827	1.63	645	35.0	41.5	7.41	7.36	10
						54.5	58.5	7.33	7.31	11
7.01	7.16	-0.15	2865		90	55.0	67.0	7.32	7.26	12
						24.8	31.5	7.50	7.47	13
7.31	7.14	+0.17	2857		160	40.0	59.0	7.36	7.27	14
						45.0	48.0	7.34	7.33	15
6.97	7.16	-0.19	2865	3.60	1440	43.5	50.0	7.35	7.31	16
						40.0	41.5	7.38	7.38	17
4.22	7.16	-2.94			45	35.0	47.0	7.41	7.35	18

by 1.9.

107:20, 1934.

125. EFFECT OF BREATHING O_2 at 3-4 ATMOSPHERES ON RESPIRATORY RATE, PULSE RATE, AND BLOOD PRESSURE: MAN

C = control period of air breathing at one atmosphere; E = experimental period of O_2 breathing at increased ambient pressure. Signs and symptoms: P = pallor, M = mental confusion, S = sweating, T = twitching movements of a myoclonic nature, G = generalized type of convulsions, O = no discernible signs or symptoms.

	Inspired O_2 Pressure atm		Respiratory Rate breaths/min		Pulse Rate beats/min		Blood Pressure				Signs and Symptoms
							Arterial mm Hg		Internal Jugular mm Hg		
	C	E	C	E	C	E	C	E	C	E	E
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
1	0.2	4.0	7	12	63	59	79	86	6.0	4.8	PM
2	0.2	4.0	19	19	79	78	85	89	6.5	5.4	PSTC
3	0.2	4.0	13		79	66	78	85	5.5		STM
4	0.2	3.5	20	12	75	51	87	91	10.0	9.6	PSTC
5	0.2	3.5	13	11	58	56	59	82	11.3	10.0	O
6	0.2	3.5	13	13	57	57	77	78	8.6	8.4	O
7	0.2	3.5	11	10	49	48	77	79	9.6	7.9	P
8	0.2	3.5	12	11	53	49	97	108	9.4	7.9	O
9	0.2	3.5	15	20	79	71	78	88	17.[illegible]	10.2	O
10	0.2	3.5	17	32	71	62	72	76	8.0	5.7	T
11	0.2	3.5	17	19	73	63	70	75	7.4	5	O
12	0.2	3.5	19	19	87	61	78	80	8.2	7.0	O
13	0.2	3.5	10	10	56	61	79	81	8.2	7.4	T
14	0.2	3.5	14	18	62	53	85	89	12.8	13.2	O
15	0.2	3.5	16	20	76	66	85	82	8.7	4.1	T
16	0.2	3.4	14		73		88	88	9.5		T
17	0.2	3.0	10	11	73	61	96	102	11.3	9.0	O

Contributor: Behnke, A. R.

Reference: Lambertsen, C. J., Kough, R. H., Cooper, D. Y., Emmel, G. L., Loeschcke, H. H., and Schmidt, C. F., J. Appl. Physiol. 5:471, 1953.

126. EFFECT OF BREATHING AIR, 6% O_2 in N_2, AND 100% O_2 AT 3.5 ATMOSPHERES ON RESPIRATORY EXCHANGE: MAN

Values are for six subjects.

	Inspired Gas	Ambient Pressure atm	Respiratory Rate breaths/min	Tidal Volume L, BTPS	Minute Volume L/min, BTPS	Alveolar pCO_2 mm Hg	CO_2 Production cc/min, STPD
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Air	1.0	12.8	0.401	5.15	41	176
2	6% O_2	3.5	12.7	0.483	6.12	42	214
3	Air	3.5	12.5	0.463	5.78	38	190
4	100% O_2	3.5	10.3	0.677	7.00	35	213
5	Air	1.0	12.5	0.511	6.34	38	216
6	6% O_2	3.5	12.7	0.468	5.95	36	188
7	Air	3.5	12.7	0.529	6.73	35	204
8	100% O_2	3.5	10.9	0.722	7.84	32	245
9	Air	1.0	20.5	0.346	7.33	40	272
10	6% O_2	3.5	16.1	0.389	6.25	38	201
11	Air	3.5	18.1	0.388	7.03	42	205
12	100% O_2	3.5	18.4	0.487	8.97	32	262
13	Air	1.0	13.2	0.433	5.69	43	201
14	6% O_2	3.5	13.2	0.382	5.05	41	164
15	Air	3.5	13.6	0.424	5.78	42	196
16	100% O_2	3.5	11.9	0.532	6.30	38	206
17	Air	1.0	12.0	0.529	6.26	39	223
18	6% O_2	3.5	12.1	0.562	6.82	38	225
19	Air	3.5	12.3	0.393	4.82	40	151
20	100% O_2	3.5	11.7	0.729	8.56	32	267
21	Air	1.0	15.6	0.487	7.57	36	223
22	6% O_2	3.5	12.0	0.524	6.28	34	173
23	Air	3.5	15.3	0.528	8.10	32	212
24	100% O_2	3.5	17.7	0.546	9.65	28	215

Contributor: Behnke, A. R.

Reference: Lambertsen, C. J., Stroud, M. W., III; Gould, R. A., Kough, R. H., Ewing, J. H., and Schmidt, C. F., J. Appl. Physiol. 5:487, 1953.

127. EFFECT OF RAPID DECOMPRESSION FROM A HIGH PRESSURE ATMOSPHERE ON BLOOD GASES: DOG

As a result of rapid decompression, from a gauge pressure of 65 lb/sq in. of air for 105 minutes' duration, nascent gas bubbles became macroscopically visible in the circulation. Massive embolization and tachypnea supervened after reduction of pressure to normal in 5-6 seconds (asphyxial period). Dogs were then recompressed at a gauge pressure of 30 lb/sq in. of air or oxygen for 84 minutes (recompression period), and finally decompressed by stages for 30 minutes until pressure was again normal (post-recompression period). Data for asphyxial period taken immediately prior to recompression; data for post-recompression period taken after breathing normal air for one hour.

	Period	O_2 Content Arterial vol %	O_2 Content Venous vol %	A-V Difference vol %	O_2 Capacity vol %	O_2 Saturation Arterial %	O_2 Saturation Venous %	pCO_2 Arterial mm Hg
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Air Inhalation							
1	Control		7.3		15.7			
2	Asphyxial	6.8						
3	Recompression	17.8	12.0	5.8				
4	Post-recompression	10.5						
5	Control	19.3	15.2	4.1	22.4	86	68	
6	Asphyxial	18.4	8.7	9.7				
7	Recompression	25.8	11.5	14.3				
8	Post-recompression	24.3	8.8	15.5	29.0	84	30	
9	Control	15.9	10.1	5.8	17.7	90	57	45.0
10	Asphyxial	5.4	0.5	4.9	22.4	24	2	59.0
11	Recompression	17.9	7.9	10.0	20.3	88	39	
12	Post-recompression	5.9	2.3	3.6	22.8	26	10	
13	Control	14.6	12.0	2.6	15.9	92	75	38.0
14	Asphyxial	6.9	2.8	4.1	18.7	37	15	51.0
15	Recompression	16.0	11.3	4.7	16.8	95	70	
16	Post-recompression	Death						
	O_2 Inhalation							
17	Control	20.9	16.7	4.2	23.1	91	72	37.0
18	Asphyxial	23.5	17.1	6.4	26.7	88	64	46.0
19	Recompression		20.5					
20	Post-recompression	26.7	16.9	9.8	28.5	94	59	
21	Control	20.6	17.0	3.6	22.8	90	75	
22	Asphyxial	14.6	7.7	6.9	26.1	56	30	
23	Recompression	31.7	20.0	11.7	31.5[1]	100	64	
24	Post-recompression	26.9	7.3	19.6	29.8	90	24	
25	Control	19.3	14.6	4.7	22.2	87	66	50.0
26	Asphyxial	18.3	10.7	7.6	26.7	70	40	60.0
27	Recompression	29.0	15.9	12.1	29.6[1]	95	54	
28	Post-recompression	22.0	11.4	10.6	24.5	90	47	

/1/ 4.2 vol % added to normal capacity by O_2 in physical solution.

Contributor: Behnke, A. R.

Reference: Behnke, A. R., Shaw, L. A., Messer, A. C., Thomson, R. M., and Motley, E. P., Am. J. Physiol. 114:526, 1936.

128. EFFECT OF DECOMPRESSION IN 5 SECONDS FROM HIGH PRESSURE ATMOSPHERES ON RESPIRATORY RATE AND BLOOD PRESSURE: DOG

	Compression Time hr	Compressed Air lb/sq in	Time Following Decompression min	Respiratory Rate breaths/min	Blood[1] Pressure mm Hg	Remarks
	(A)	(B)	(C)	(D)	(E)	(F)
1	4	45	12	20	110	Dog in good condition following day.
2		45	36	20	110	
3	1.5	60	4	24	120-130	Increased respiratory rate subsided spontaneously.
4		60	8	22	120-130	
5		60	14	34	120-130	
6		60	17	24	120-130	
7		60	21	50	120-130	
8		60	25	54	120-130	
9		60	94	36	120-130	
10		60	200	19	120-130	
11	2	60	3	14	124	Decompression precipitated massive embolization and respiratory rate failure.
12		60	7	14	120	
13		60	25	9	140	
14		60	33	8	60	

/1/ Recorded from a manometer connected to a cannula in femoral artery.

128. EFFECT OF DECOMPRESSION IN 5 SECONDS FROM HIGH PRESSURE ATMOSPHERES ON RESPIRATORY RATE AND BLOOD PRESSURE: DOG (Concluded)

	Compression Time hr (A)	Compressed Air lb/sq in (B)	Time Following Decompression min (C)	Respiratory Rate breaths/min (D)	Blood[1] Pressure mm Hg (E)	Remarks (F)
15	2	60	37	7	40	Decompression precipitated massive embolization and respiratory rate failure.
16		60	45	7		
17		60	46	Failure		
18	2	60	3	7	90	Spontaneous subsidence of tachypnea.
19		60	11	19		
20		60	14	20	112	
21		60	27	38		
22		60	19	69		
23		60	21	78		
24		60	26	92		
25		60	32	47		
26		60	36	17	90	
27		60	58	11	90	
28	0.55	75	1	9	64	Precipitous respiratory rate failure which did not respond to recompression.
29		75	3	Failure	110 to 25	
30	Recompression				120	
31	Recompression				92	
32	Recompression				88	

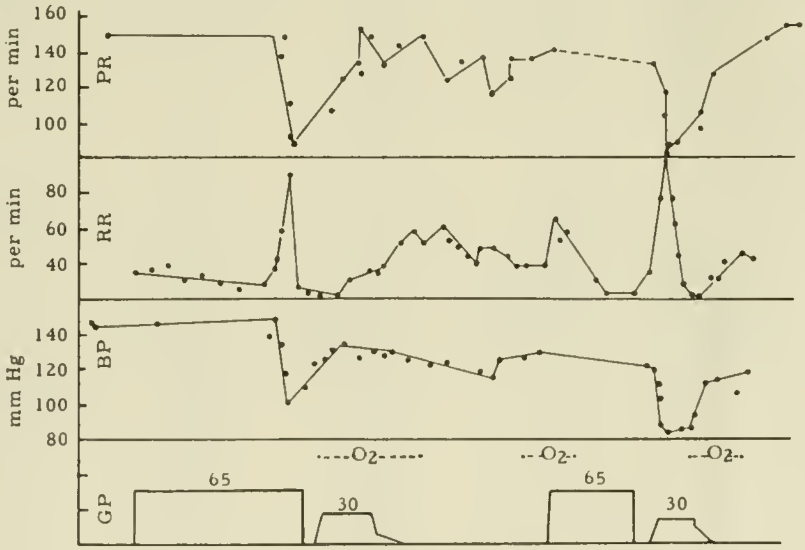
/1/ Recorded from a manometer connected to a cannula in femoral artery.

Contributor: Behnke, A. R.

Reference: Behnke, A. R., Medicine 24:381, 1945.

129. EFFECT OF DECOMPRESSION AND RECOMPRESSION ON BLOOD PRESSURE, RESPIRATORY RATE, AND PULSE RATE: DOG

Alterations in blood pressure, respiratory rate and pulse rate of dog decompressed in ten seconds from a gauge pressure of 65 lb after $1\frac{1}{2}$ hours' exposure, followed by recompression (interval of ten minutes) to a pressure of 30 lb (oxygen) for twenty-five minutes. Pressure was then lowered to atmospheric in twelve minutes, and oxygen inhalation continued for seventeen minutes. Preceded by period of oxygen breathing (thirty minutes), compression of dog was again repeated at a pressure of 65 lb for period of forty-five minutes, followed by ten seconds' decompression. After interval of twelve minutes, dog was recompressed to a pressure of 30 lb for twenty minutes (oxygen inhalation).



GP = gauge pressure
BP = blood pressure
RR = respiratory rate
PR = pulse rate.

Contributor: Behnke, A. R.

Reference: Behnke, A. R., U. S. Nav. M. Bull. 35:61, 1937.

130. EFFECT OF DECOMPRESSION ON INTERNAL PRESSURES: DOG

Unprotected dogs decompressed from 100-200 ft equivalent depth with trachea closed, developed pulmonary interstitial emphysema and air embolism when intratracheal pressure reached a critical level of approximately 80 mm Hg. However, it appears that the critical factor in this development is a transpulmonic pressure of 60-70 mm Hg, or a transatrial pressure in excess of 55-65 mm Hg, rather than an absolute level of the intratracheal pressure. Overdistension of the lung was prevented by application of thoraco-abdominal binders, but not by abdominal binders alone. Group A = animals without binders that developed air embolism; Group B = animals without binders that did not develop air embolism; Group C = animals with abdominal binders that developed air embolism; Group D = animals with thoraco-abdominal binders that did not develop air embolism. Values represent pressures in mm Hg based on means of all animals weighted by the number of ascents.

	Pressure	Group A					Group B				
		Subjects no.	Ascents no.	Compressed	Decompressed	Gradient max.	Subjects no.	Ascents no.	Compressed	Decompressed	Gradient max.
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
1	Intratracheal	7	8	1.9	88.6		5	9	2.0	59.0	
2	Intrapleural	4	5	-3.0	9.4		3	5	-6.3	7.9	
3	Intra-abdominal	4	4	-1.5	18.8		4	6	0.9	11.8	
4	Pulmonary arterial	6	7	9.8	54.9		4	8	3.8	27.2	
5	Left atrial	6	7	1.7	19.8		4	6	-5.3	13.8	
6	Systemic arterial	7	8	103.2	22.8		5	9	90.7	36.0	
7	Systemic venous	5	6	1.1	17.1		5	9	-1.9	18.7	
8	Transpulmonary[1]	4	5			68.1	3	5			54.2
9	Transatrial[2]	5	7			63.6	4	6			43.3
10	Transcapillary[3]	5	6			31.2	3	5			13.7

	Pressure	Group C					Group D				
		Subjects no.	Ascents no.	Compressed	Decompressed	Gradient max.	Subjects no.	Ascents no.	Compressed	Decompressed	Gradient max.
	(A)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	(U)
1	Intratracheal	2	2	5.0	130.0		2	8	3.6	82.1	
2	Intrapleural	2	2	-4.0	31.0		2	8	-4.2	55.4	
3	Intra-abdominal	1	1	5.0	30.0		2	8	4.2	42.0	
4	Pulmonary arterial	2	2	13.0	55.0		2	8	8.2	68.5	
5	Left atrial	2	2	-3.0	36.0		2	8	2.4	56.1	
6	Systemic arterial	2	2	97.5	43.0		2	8	125.4	104.1	
7	Systemic venous	2	2	9.5	30.0		2	8	5.4	71.8	
8	Transpulmonary[1]	2	2			99.0	2	8			29.2
9	Transatrial[2]	2	2			94.0	2	8			26.0
10	Transcapillary[3]	2	2			19.0	2	8			12.5

/1/ Transpulmonary = intratracheal minus intrapleural. /2/ Transatrial = intratracheal minus left atrial.
/3/ Transcapillary = pulmonary arterial minus left atrial.

Contributor: Schaefer, K. E.

Reference: Schaefer, K. E., McNulty, W. P., Jr., Carey, C., and Liebow, A. A., J. Appl. Physiol., in press.

131. EFFECT OF DRUGS ON PULMONARY

Drugs are listed alphabetically, using a well-known name. Use of trade names is for informative purposes only and is expressed as % increase or decrease from the control value (100%). In a few instances only + or - signs are used wise indicated. When no significant difference exists over a dosage range, the data are averaged over the range.

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate Control breaths/min	Respiratory Rate Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Acetazolamide	25	Oral	Man		9	+11
2		25	Oral	Dog	Morphine and	6	0
3		5-100	IV	Dog	pentobarb.		-7
4		5-100	IV	Dog	15% O_2		-32
5	Acetic acid	10 cc 0.1N	IV	Rabbit	Urethane	60	-20
6	Acetone	15 cc 15%	IV	Rabbit	Urethane	42	+67
7		15 cc 20%	IV	Rabbit	Urethane	48	+150
8		10 cc 30%	IV	Rabbit	Urethane	65	+31
9	2-Acetoxy-	200	Oral	Cat		36	+3
10	phenanthrene	300	Oral	Cat		36	+17
11	3-Acetoxy-	200	Oral	Cat		42	0
12	phenanthrene	300	Oral	Cat		42	0
13	Acetylcodeine	0.05-1.0	SC	Rabbit			-17
14	HCl	0.05-1.0	SC	Rabbit	8% CO_2		-16
15		2.0-10.0	SC	Rabbit			-39
16		2.0-10.0	SC	Rabbit	8% CO_2		-37
17	Acetyldihydrocodeine	0.2-2.0	SC	Rabbit			-10
18	HCl	0.2-2.0	SC	Rabbit	8% CO_2		-6
19		5-20	SC	Rabbit			-25
20		5-20	SC	Rabbit	8% CO_2		-25
21	Acetyldihydroiso-	0.2-1.0	SC	Rabbit			-11
22	codeine acid tartrate	0.2-1.0	SC	Rabbit	8% CO_2		-8
23		2.0-10.0	SC	Rabbit			-52
24		2.0-10.0	SC	Rabbit	8% CO_2		-55
25	Acetylguanidine HCl	5.0	SC	Rabbit	Urethane	68	+53
26	Acetylhydroxycodeinone	0.3-1.0	SC	Rabbit			-19
27	HCl	0.3-1.0	SC	Rabbit	8% CO_2		-14
28		3.0	SC	Rabbit			-50
29		3.0	SC	Rabbit	8% CO_2		-50
30		5.0	SC	Rabbit			-75
31		5.0	SC	Rabbit	8% CO_2		-68
32	Acetylisocodeine HCl	0.1-0.5	SC	Rabbit			-12
33		0.1-0.5	SC	Rabbit	8% CO_2		-7
34		1.0-2.0	SC	Rabbit			-39
35		1.0-2.0	SC	Rabbit	8% CO_2		-29
36		5.0-10.0	SC	Rabbit			-62
37		5.0-10.0	SC	Rabbit	8% CO_2		-56
38	Alcohol (ethyl, 95%)	1.5-5 cc	IP	Rabbit		56	-4
39	Allopseudocodeine HCl	5-30	SC	Rabbit		56	-11
40		5-30	SC	Rabbit	CO_2	66	-3
41	Aminoguanidine HCl	2	SC	Rabbit	Urethane	180	+24
42	Aminophylline	3	IV	Man		11	0
43		3	IV	Man	2.1-6% CO_2	15	-12
44		6	IV	Man			+18
45		6	IV	Man	2.1-6% CO_2		+32
46		25	SC	Man		13	+8
47		25	SC	Man	3% CO_2	14	0
48		25	SC	Man	5% CO_2	17	-19
49	p-(2-Aminopropyl)-	70 mg	Oral	Man		11	+27
50	phenol	15-20 mg	IM	Man		11	+10
51	Amobarbital	2.9-10.0	Oral	Man		12	+14
52	Amphetamine	10 mg	Oral	Man		13	-2
53	sulfate	30 mg	Oral	Man			+5
54		10 mg	IM	Man			-21
55		5-50	Oral	Man		7	-34
56		5%	Aerosol	Man		8	-27
57	Amyldihydro-	0.0001-0.005	SC	Rabbit			-7
58	morphinone HCl	0.0001-0.005	SC	Rabbit	8% CO_2		-6
59		0.01-0.02	SC	Rabbit			-37

/1/ Arterial. /2/ Alveolar.

in no way implies endorsement by The National Academy of Sciences-The National Research Council. Drug response to indicate increase or decrease when quantitative data are not available. Dose is expressed in mg/kg, unless other-Values enclosed in parentheses show the highest and lowest % change for that particular dosage level.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
690	-11	6.39	0				-12	39.9[1]	-2[1]	85	1
	-28		-28				-2	53.7[1]	-1[1]	85	2
	+28		+13				-7		+24[1]	85	3
	+65		+15				-4		+12[1]	85	4
15	+67	0.885	+35					37.5[1]	+3[1]	1	5
13	+8	0.980	+79					28.0[1]	-11[1]	1	6
24	+17	1.152	+192					28.5[1]	-9[1]	1	7
15	-7	0.975	+22					33.5[1]	-11[1]	1	8
										2	9
										2	10
										2	11
										2	12
			-10				+2			3	13
			-20							3	14
			-27				-9			3	15
			-44							3	16
			-5				+8			3	17
			-8							3	18
			-12				+14			3	19
			-30							3	20
			-3				+3			3	21
			-8							3	22
			-39				-3			3	23
			-59							3	24
										5	25
			-10				+2			4	26
			-15							4	27
			-35				-2			4	28
			-57							4	29
			-56				-17			4	30
			-72							4	31
			-8				+4			3	32
			-9							3	33
			-25				-10			3	34
			-31							3	35
			-47				-12			3	36
			-61							3	37
9	-15	0.500	-17							6	38
21	+6	1.176	-4			25	+8			7	39
45	0	2.970	-3							7	40
										5	41
689	+19	6.55	+19					37.5[2]	-8[2]	8	42
1258	+26	18.70	+16					45.0[2]	-4[2]	8	43
	-16		+10						-6[2]	8	44
	-1		+36						-6[2]	8	45
630	+36	8.2	0							9	46
1110	+4	15.4	+5							9	47
1427	+21	24.7	-3							9	48
363	-22	4.0	0			171	+8			18	49
572	-14	5.3	+6			259	0			18	50
						231	+3			11	51
481	-11	6.4	-13			264	-8			18	52
	+4		+9				+14			18	53
	+3		-19				-3			18	54
696	+49	5.0	-8	3.48	+3					19	55
743	+55	5.4	+6	3.9	+15					20	56
			-2				+6			10	57
			-7							10	58
			-23				-10			10	59

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate Control breaths/min	Respiratory Rate Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
60	Amyldihydro-	0.01-0.02	SC	Rabbit	8% CO_2		-32
61	morphinone HCl	0.05-0.50	SC	Rabbit			-79
62	(concluded)	0.05-0.50	SC	Rabbit	8% CO_2		-86
63	Apomorphine	1.0	SC	Rabbit		28	+164
64	Atropine sulfate	0.05 mg	SC	Man			
65		0.05 mg	IV	Man			
66		1.29 mg	Oral	Man			
67		1%	Aerosol	Man		13	-52
68		1%	Aerosol	Man		6	-4
69		0.4-2.0 mg	IV	Dog	Chloralose		
70	Azure A	0.1-0.5	IV	Rabbit	Urethane		+3
71		1.0-5.0	IV	Rabbit	and		+19
72		7.5-10.0	IV	Rabbit	pentobarb.		+7
73	Barbital sodium	5-19	Oral	Man		12	+15
74	2-(Benzhydryloxy)-N, N-dimethyl-ethylamine HCl	100 mg	IV	Dog	Pentobarb.		
75	2-(-N-Benzylanilino-	100 mg	IV	Dog	Pentobarb.		
76	methyl)-imidazoline	50	IM	Mice	20% O_2		0
77		50	IM	Mice	16% O_2		-6
78		50	IM	Mice	14-10% O_2		-23
79	Benzyldihydrodesoxy-	0.2-5.0	SC	Rabbit			-8(+3 to -16)
80	morphine-D HCl	0.2-5.0	SC	Rabbit	8% CO_2		-7(-2 to -12)
81		10.0-40.0	SC	Rabbit			-14(-11 to -17)
82		10.0-40.0	SC	Rabbit	8% CO_2		-19(-14 to -26)
83	Benzyldihydromorphine	0.2-5.0	SC	Rabbit			-7(-3 to -13)
84	HCl	0.2-5.0	SC	Rabbit	8% CO_2		-5(-3 to -6)
85		10-20	SC	Rabbit			-15
86		10-20	SC	Rabbit	8% CO_2		-16(-13 to -19)
87		40	SC	Rabbit			+40
88		40	SC	Rabbit	8% CO_2		+7
89	Benzyldihydro-	0.01-0.2	SC	Rabbit			-11(-2 to -23)
90	morphinone HCl	0.01-0.2	SC	Rabbit	CO_2		-8(+0.4 to -19)
91		0.5-2.0	SC	Rabbit			-41(-35 to -47)
92		0.5-2.0	SC	Rabbit	CO_2		-37(-32 to -43)
93	Benzylethyl-	10%	Aerosol	Man		9	-78
94	methylamine	5%	Aerosol	Man		8	-47
95	Benzylmorphine HCl	0.1-3.0	SC	Rabbit			-3(+2 to -10)
96		0.1-3.0	SC	Rabbit	CO_2		+0.2(+4 to -6)
97		5.0-10.0	SC	Rabbit			-9(-6 to -12)
98		5.0-10.0	SC	Rabbit	CO_2		-9(-4 to -14)
99		20	SC	Rabbit			+16
100		20	SC	Rabbit	CO_2		+12
101	Benzylmorphine-	0.5-20.0	SC	Rabbit			-10(-4 to -16)
102	6-methyl ether	0.5-20.0	SC	Rabbit	8% CO_2		-7(-4 to -11)
103	acid sulfate	50.0	SC	Rabbit			+14
104		50.0	SC	Rabbit	8% CO_2		
105	Bromocodeinone	0.05-1.0	SC	Rabbit			-2(+6 to -12)
106		0.05-1.0	SC	Rabbit	6-10% CO_2		-3(+3 to -9)
107	Butallylonal sodium	42	IV	Dog		24	-17
108	Butethal	200 mg	Oral	Man			+3
109		300 mg	Oral	Man			+44
110		400 mg	Oral	Man			+10
111	Caffeine	5-10%	Aerosol	Man		11	+36
112		250 mg	SC	Man	3% CO_2		+23
113		250 mg	SC	Man	5% CO_2		+52
114		10	IM	Man	Morphine	9	+23
115		25 mg	IM	Man		12	+10
116		25 mg	IM	Man	3% CO_2		+1
117		25 mg	IM	Man	5% CO_2		+12
118		30	IV	Cat	Phenobarb.		+68
119		30	IV	Cat	Chlorbutanol		+31

MAN AND LABORATORY ANIMALS (Continued)

value (100%). Dose is expressed in mg/kg, unless otherwise indicated.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
			-32							10	60
			-60				-27			10	61
			-88							10	62
14	0	0.395	+167							12	63
612	-15									13	64
493	+15									13	65
			+3				+3			14	66
450	+122	5.62	+7							15	67
820	+5	4.52	-5	3.5	-3					16	68
166	-16									13	69
	0									17	70
	+10									17	71
	-8									17	72
						211	-3			11	73
			+44							26	74
			+16							26	75
										27	76
										27	77
										27	78
			-0.4(-9 to +10)				+6(+3 to +9)			28	79
			-7(+3 to -16)							28	80
			-13(-10 to -16)				+8(+6 to +11)			28	81
			-25(-17 to -38)							28	82
			-1.3(+5 to -9)				+4(+2 to +6)			28	83
			-6(+3 to -7)							28	84
			-17(-11 to -24)				+6(+4 to +8)			28	85
			-21(-16 to -26)							28	86
			+10				+14			28	87
			-12							28	88
			-2(+6 to -11)				+4(+11 to +2)			10	89
			-9(+4 to -23)							10	90
			-22(-14 to -26)				-7(-4 to -11)			10	91
			-43(-40 to -46)							10	92
550	+218	4.95	-29							15	93
695	+55	5.6	-14	3.4	+7					16	94
			+5(+2 to +14)				+6(+2 to +8)			28	95
			-0.6(+2 to -10)							28	96
			-9(-7 to -11)				+6(+3 to +9)			28	97
			-13(-11 to -16)							28	98
			-7				+14			28	99
			-10							28	100
			-8(-1 to -17)				+7(+3 to +14)			28	101
			-11(-3 to -25)							28	102
			+13							28	103
			+17							28	104
			0(+5 to -6)				+9(+2 to +16)			4	105
			-6(+14 to -16)							4	106
220	0	5.28	-17			150	-13			29	107
							-7			11	108
							+6			11	109
							-7			11	110
631	-28	6.45	+8	4.1	-5					16	111
										30	112
										30	113
529	-3	4.5	+20							31	114
626	-7	7.7	+3							9	115
	+11		+12							9	116
	+3		+16							9	117
			+47							32	118
			+40							32	119

Drug response is expressed in % increase or decrease from the control

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate: Control breaths/min	Respiratory Rate: Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
120	Caffeine (concluded)	30	IV	Dog	Phenobarb.		+14
121		30	IV	Dog	Pentobarb.		+61
122		200 mg	IV	Rabbit	Tribromoethanol		+150
123	Carbachol	0.5-2%	Aerosol	Man		7	+165
124	Carbon dioxide	2%	Inhaled	Man		14	+6
125		3.5%	Inhaled	Man			+10
126		5.0%	Inhaled	Man			+28
127		3.0%	Inhaled	Man		15	+53
128		5-7%	Inhaled	Man			
129		2.0%	Inhaled	Cat		30	+3
130		4.0%	Inhaled	Cat			+3
131		6.0%	Inhaled	Cat			+17
132		8.0%	Inhaled	Cat			+23
133	Carbon monoxide	1.0%	Inhaled	Dog	Amytal	13	+123
134	Chlorallyl-nor-codeine chlorhydrate	20	SC	Rabbit		23	+130
135	Chloralose	89.5	IV	Dog		18	-22
136		75	IP	Cat		34	-67
137		75	IP	Cat	2% CO_2		-71
138		75	IP	Cat	4% CO_2		-70
139		75	IP	Cat	6-8% CO_2		-70
140	Chlorprophenpyridaminemaleate	0.4 mg	IV	Dog	Pentobarb.	13	-2
141	Codeine sulfate and HCl	20 mg	SC	Man			
142		60 mg	SC	Man			
143		120 mg	SC	Man			
144		2-5	SC	Rabbit			-21
145		2-5	SC	Rabbit	CO_2		-19
146		10-20	SC	Rabbit			-22
147		10-20	SC	Rabbit	CO_2		-19
148		30	SC	Rabbit		30	+33
149	Cyclobarbital	200 mg	Oral	Man			+9
150		400 mg	Oral	Man			+9
151		600 mg	Oral	Man			+1
152	d-Desoxyephedrine HCl	0.5-1.0	SC	Rat		143	+32
153		1.5-2.0	SC	Rat			+45
154		2.5-3.0	SC	Rat			+44
155		0.5-10.0	SC	Guinea pig		75	+19
156		20.0	SC	Guinea pig			+92
157	Diacetyldihydrohydroxycodeine-B acid tartrate	0.3-1.0	SC	Rabbit			-9
158		0.3-1.0	SC	Rabbit	6-10% CO_2		-6
159		3.0-5.0	SC	Rabbit			-40
160		3.0-5.0	SC	Rabbit	6-10% CO_2		-27
161		10.0-20.0	SC	Rabbit			-58
162		10.0-20.0	SC	Rabbit	6-10% CO_2		-52
163	Diacetyldihydrohydroxycodeine-C acid tartrate	0.05-1.0	SC	Rabbit			-11
164		0.05-1.0	SC	Rabbit	6-10% CO_2		-6
165		3.0-5.0	SC	Rabbit			-57
166		3.0-5.0	SC	Rabbit	6-10% CO_2		-43
167		10.0	SC	Rabbit			-76
168		10.0	SC	Rabbit	6-10% CO_2		-77
169	Diacetyldihydromorphine HCl	0.1-0.3	SC	Rabbit			-18
170		0.1-0.3	SC	Rabbit	CO_2		-2(0 to -4)
171		0.5-2.0	SC	Rabbit			-52
172		0.5-2.0	SC	Rabbit	CO_2		-46
173		3.0-10.0	SC	Rabbit			-81
174		3.0-10.0	SC	Rabbit	CO_2		-82
175	Diacetylmorphine HCl	0.01-0.1	SC	Rabbit			-28(-8 to -40)
176		0.01-0.1	SC	Rabbit	CO_2		-15
177		0.3-10.0	SC	Rabbit			-84
178		0.3-10.0	SC	Rabbit	CO_2		-81
179	Diallylbarbituric acid	3.0	Oral	Man		11	+6

MAN AND LABORATORY ANIMALS (Continued)

value (100%). Dose is expressed in mg/kg, unless otherwise indicated.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
			+16							32	120
			+61							32	121
										33	122
800	-38	5.11	+43	3.75	+8					16	123
										34	124
										34	125
										34	126
609	+120	9.4	+249	7.5	-1					35	127
			+360							36	128
13	+45	0.382	+50							37	129
	+188		+197							37	130
	+380		+459							37	131
	+512		+654							37	132
85	-19	1.1	+82							38	133
22	-32	0.510	+55							12	134
231	+5	4.16	-19			137	-17			29	135
11	+56	0.373	-52							37	136
	+30		-62							37	137
	-4		-76							37	138
	-38		-82							37	139
106	+6	1.4	+4							26	140
			-8							39	141
			-18							40	142
			-31							40	143
	+7						-1			7	144
	-3									7	145
	+12						+31			7	146
	-14									7	147
8	+112	0.242	+186							12	148
							-19			11	149
							+4			11	150
							0			11	151
2	+7	0.282	+43							49	152
	+19		+70							49	153
	+3(+22 to -16)		+50							49	154
	-15(+9 to -28)		-2(-39 to +49)							49	155
	+15		+145							49	156
			-6				+1(+4 to -5)			4	157
			-8							4	158
			-26				-2			4	159
			-26							4	160
			-41				-10			4	161
			-56							4	162
			-4(+5 to -11)				+2			4	163
			-7(+2 to -16)							4	164
			-31				-4			4	165
			-45							4	166
			-55				-24			4	167
			-79							4	168
	+12		-8				+1(+3 to -1)			45	169
	-0.5(+1 to -2)		-2							45	170
	+31		-36				-10			45	171
	-9		-50							45	172
	+91		-65				-11(+13 to -23)			45	173
	-7		-84							45	174
	+21		-13(+4 to -29)				-4(+2 to -12)			45	175
	0(-4 to +2)		-15							45	176
	+108		-69				-23			45	177
	+5(+36 to -15)		-80							45	178
						219	-3			11	179

Drug response is expressed in % increase or decrease from the control

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate	
						Control breaths/min	Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
180	Diallylbarbituric acid	6.0	Oral	Man			-17
181	(concluded)	7.0	Oral	Man			+9
182	6, 7-Diethoxy tetra- hydroisoquinoline	0.6-2.6	IV	Cat, dog	Anesthetized		0
183	1, 2, 3-tri-(β-Di-	0.5 mg	IV	Man	Cyclopropane		
184	ethylamino-	1.0 mg	IV	Man	Cyclopropane		
185	ethoxy) benzene	1.5 mg	IV	Man	Cyclopropane		
186	triethiodide (Flaxedil)	2.0 mg	IV	Man	Cyclopropane		
187	Diethylaminomethyl	10%	Aerosol	Man		11	-29
188	benzodioxane	1-30%	Aerosol	Man		9	-21
189	Ac-2, 2-Diethyl- aminomethyl tetra- hydronaphthol HCl	50	SC	Rabbit		37	+16
190	Digitolal	100 mg	IV	Man			
191	Digitoxin	1.4 mg	IV	Man			
192		1.4 mg	IV	Man	CO_2		
193		2.2 mg	IV	Man			
194		2.2 mg	IV	Man	CO_2		
195	Dihydro-allo-	5.0-20.0	SC	Rabbit			-21
196	pseudocodeine acid	5.0-20.0	SC	Rabbit	CO_2		-21
197	tartrate	30.0-40.0	SC	Rabbit			-42
198		30.0-40.0	SC	Rabbit	CO_2		-32
199	Dihydrocodeine	30 mg	SC	Man			
200	acid tartrate	30 mg	SC	Man	5% CO_2		
201		2.0-3.0	SC	Rabbit			-10
202		2.0-3.0	SC	Rabbit	CO_2		-65
203		5.0-10.0	SC	Rabbit			-30
204		5.0-10.0	SC	Rabbit	CO_2		-28
205		15.0-30.0	SC	Rabbit			-48
206		15.0-30.0	SC	Rabbit	CO_2		-47
207		50.0	SC	Rabbit			-28
208		50.0	SC	Rabbit	CO_2		-19
209	Dihydrocodeinone	5 mg		Man			
210	bitartrate	0.1-0.5	SC	Rabbit			-19
211		0.1-0.5	SC	Rabbit	CO_2		-14
212		1.0-5.0	SC	Rabbit	CO_2		-40
213		1.5-5.0	SC	Rabbit			-39
214		10	SC	Rabbit			-63
215		10	SC	Rabbit	CO_2		-57
216	Dihydrocodeinone	0.1-0.2	SC	Rabbit			-11
217	enol acetate	0.1-0.2	SC	Rabbit	8% CO_2		-4
218		0.5-2.0	SC	Rabbit			-37
219		0.5-2.0	SC	Rabbit	8% CO_2		-30
220		5.0	SC	Rabbit			-62
221		5.0	SC	Rabbit	8% CO_2		-68
222	Dihydrohydroxy-	0.5-50.0	SC	Rabbit			-3(+3 to -10)
223	codeine-A	0.5-50.0	SC	Rabbit	6-10% CO_2		-4(+4 to -8)
224	Dihydrohydroxy-	0.05-0.2	SC	Rabbit			+3
225	codeine-B	0.05-0.2	SC	Rabbit	6-10% CO_2		+1
226		0.5-1.0	SC	Rabbit			-18
227		0.5-1.0	SC	Rabbit	6-10% CO_2		-13
228		3.0-5.0	SC	Rabbit			-43
229		3.0-5.0	SC	Rabbit	6-10% CO_2		-34
230		10.0-20.0	SC	Rabbit			-70
231		10.0-20.0	SC	Rabbit	6-10% CO_2		-65
232	Dihydrohydroxy-	0.1-1.0	SC	Rabbit			-5
233	codeine-C	0 1-1.0	SC	Rabbit	6-10% CO_2		-4
234		3.0-10.0	SC	Rabbit			-38
235		3.0-10.0	SC	Rabbit	6-10% CO_2		-37
236		20	SC	Rabbit			-55
237		20	SC	Rabbit	6-10% CO_2		-56

/1/ Alveolar.

MAN AND LABORATORY ANIMALS (Continued)

value (100%). Dose is expressed in mg/kg, unless otherwise indicated.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
							+11			11	180
							+5			11	181
	-		-							44	182
			-11							78	183
			-35							78	184
			-50							78	185
			-88							78	186
775	+32	8.14	-6							15	187
648	+42	5.73	-8	4.12	-1					16	188
29	+3	1.069	+20			30	+93			46	189
						241	+2			47	190
			-1						+1[1]	48	191
			-16					42.0[1]	0[1]	48	192
			-1						+4[1]	48	193
			-30					42.0[1]	0[1]	48	194
	+6		-17				+7(+3 to +9)			43	195
	0		-21							43	196
	+22		-28				-5(0 to -9)			43	197
	0		-33							43	198
		9.7	-4							42	199
		16.7	-10							42	200
	+2		-8				0			43	201
	+4		-3							43	202
	+15		-20				0			43	203
	-3		-30							43	204
	+32		-33				+4			43	205
	-7		-51							43	206
	+43		+4				+40			43	207
	-11		-28							43	208
			-4							39	209
	+12						0			41	210
	-1									41	211
	+15						+9			41	212
	-16									41	213
	+71						+14			41	214
	+2									41	215
			-5				+0.2			10	216
			-7							10	217
			-23				-8			10	218
			-34							10	219
			-48				-17			10	220
			-76							10	221
			-0.2(+3 to -7)				+3(-9 to +17)			4	222
			-0.5(+15 to -9)							4	223
			+7				+5			4	224
			+6							4	225
			-9				+3			4	226
			-12							4	227
			-33				-2			4	228
			-42							4	229
			-50				-11			4	230
			-67							4	231
			+6				+3(+9 to -3)			4	232
			-2							4	233
			-30				-3			4	234
			-46							4	235
			-52				-22			4	236
			-69							4	237

Drug response is expressed in % increase or decrease from the control

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate Control breaths/min	Respiratory Rate Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
238	Dihydrohydroxy-	0.01-0.1	SC	Rabbit			-7
239	codeinone HCl	0.01-0.1	SC	Rabbit	6-10% CO_2		-3
240		0.3-1.0	SC	Rabbit			-30
241		0.3-1.0	SC	Rabbit	6-10% CO_2		-28
242		3.0-5.0	SC	Rabbit			-73
243		3.0-5.0	SC	Rabbit	6-10% CO_2		-76
244		10	SC	Rabbit			-84
245		10	SC	Rabbit	6-10% CO_2		-94
246	Dihydroisocodeine	30 mg	SC	Man			
247	acid tartrate	30 mg	SC	Man	5% CO_2		
248		1.0-2.0	SC	Rabbit			-22
249		1.0-2.0	SC	Rabbit	CO_2		-12
250		5.0-20.0	SC	Rabbit			-55
251		5.0-20.0	SC	Rabbit	CO_2		-50
252		35.0-50.0	SC	Rabbit			-61
253		35.0-50.0	SC	Rabbit	CO_2		-62
254	Dihydromorphine	0.1-2.0	SC	Rabbit			-25(+1 to -37)
255	HCl	0.1-2.0	SC	Rabbit	CO_2		-22
256		3.0-10.0	SC	Rabbit			-56
257		3.0-10.0	SC	Rabbit	CO_2		-50
258	Dihydromorphinone	0.01-0.25	SC	Rabbit			-27(-8 to -44)
259	HCl	0.01-0.25	SC	Rabbit	CO_2		-19(-3 to -39)
260		0.5-10.0	SC	Rabbit			-62
261		0.5-10.0	SC	Rabbit	CO_2		-61
262	Dihydropseudo-	50.0-150.0	SC	Rabbit			-7(+20 to -19)
263	codeine HCl	50.0-150.0	SC	Rabbit	CO_2		-9(-2 to -14)
264	5, 6-Dihydroxy tetra-hydroisoquinoline	0.24-4.5	IV	Cat, dog	Anesthetized		-
265	6, 7-Dihydroxy tetra-hydroisoquinoline	0.24-4.5	IV	Cat, dog	Anesthetized		-
266	Dimenhydrinate	10 mg	IV	Dog	Pentobarb.	11	+10
267	5, 6-Dimethoxy tetra-hydroisoquinoline	1.0-5.1	IV	Cat, dog	Anesthetized		-
268	6, 7-Dimethoxy tetra-hydroisoquinoline	1.0-5.1	IV	Cat, dog	Anesthetized		-
269	Ac-2, 2-Dimethyl-aminomethyl tetra-hydronaphthol HCl	150	SC	Rabbit		35	+9
270	Dimethyl guanidine HCl	5	SC	Rabbit	Urethane	70	+26
271	Dimethyltoluthionine Cl	0.1	IV	Rabbit	Pentobarb.		0
272		0.5-2.0	IV	Rabbit	and		+4
273		5.0-7.5	IV	Rabbit	urethane		+18
274		10.0	IV	Rabbit	Pentobarb. and urethane		-6
275	Dinitrophenol	10.0-20.0	SC	Dog	Pentobarb.	16	+275
276		10.0	SC	Rabbit	Morphine		+11
277		20.0	SC	Rabbit	Morphine		+96
278		40.0	SC	Rabbit	Morphine		+43
279		20.0	SC	Rabbit	Chloral		+59
280		20.0	SC	Rabbit	Alcohol		+49
281		20.0	SC	Rabbit	Pentobarb.		+36
282		5.0	IM	Rabbit			+6
283		10.0	IM	Rabbit			+8
284		20.0-60.0	IM	Rabbit			+50
285		80.0	IM	Rabbit			+23
286	2, 4-Dinitrophenyl-	0.02-0.50	SC	Rabbit			-15(-2 to -35)
287	morphine HCl	0.02-0.50	SC	Rabbit	8% CO_2		-8(-1 to -24)
288		1.0-20.0	SC	Rabbit			-39(-28 to -55)
289		1.0-20.0	SC	Rabbit	8% CO_2		-34(-15 to -56)
290	Diphenyl guanidine symm. HCl	1	SC	Rabbit	Urethane	136	+10
291	Ephedrine	5.0-50.0	Oral	Man		8	-3
292		0.5	SC	Man	Morphine	7	+28

MAN AND LABORATORY ANIMALS (Continued)

value (100%). Dose is expressed in mg/kg, unless otherwise indicated.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
			+5				+6			4	238
			-1							4	239
			-20				-3			4	240
			-33							4	241
			-57				-3			4	242
			-77							4	243
			-62				-15			4	244
			-93							4	245
		9.8	-17							42	246
		16.3	-25							42	247
	+8		-16				0			43	248
	-2		-14							43	249
	+29		-42				-10			43	250
	-3		-50							43	251
	+19		-53				+9			43	252
	-30		-73							43	253
	+8(-2 to +17)		-19(0 to -31)				+1(0 to +4)			41	254
	0(+10 to -12)		-22							41	255
	+29		-40				-3(+5 to -10)			41	256
	-4(+5 to -14)		-52							41	257
	+11(+2 to +25)		-21(-7 to -30)				+4(0 to +5)			41	258
	-3(0 to -4)		-21(-6 to -39)							41	259
	+26(+3 to +60)		-52				-2(+5 to -8)			41	260
	-16(-4 to -30)		-67							41	261
	0(+13 to -13)		-8(+5 to -18)				+5(0 to +9)			43	262
	-5(-2 to -7)		-15(-7 to -20)							43	263
	-		-							44	264
	-		-							44	265
124	+10	1.40	+21							26	266
	0		0							44	267
	0		0							44	268
18	+11	0.627	+19			37	+3			46	269
										5	270
	0									17	271
	+4									17	272
	+10									17	273
	-20									17	274
147	+321	1.76	+1809			86	+731			50	275
										6	276
	+107		+306							6	277
	-70		-57							6	278
	+22		+93							6	279
	+68		+150							6	280
	+46		+100							6	281
	-11		-6							51	282
	+43		+49							51	283
	+55		+135							51	284
	+209		+272							51	285
			-2(+2 to -8)				-0.2			28	286
			-6(+5 to -25)							28	287
			-21(-6 to -31)				-5.5(-12 to +2)			28	288
			-35(-11 to -57)							28	289
										5	290
738	+15	5.55	+4	3.78	+4					19	291
728	+1	5.10	+29							31	292

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate Control breaths/min	Respiratory Rate Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
293	Ephedrine (concluded)	0.5-1.0	IM	Fox			
294		0.05	IM	Dog			
295		0.25-0.85	IM	Dog			
296	Epinephrine HCl	0.1-1.0%	Aerosol	Man		7	-30
297		20 μg	IV	Man			
298		160 μg/kg	SC	Fox			
299		160 μg/kg	IP	Fox			
300		5 μg/kg	IM	Dog			
301		10-20 μg/kg	IM	Dog			
302		50 μg/kg	IM	Dog			
303		80 μg/kg	IM	Dog			
304		125 μg/kg	IM	Dog			
305	Ergotamine	0.05	IV	Cat	Chloralose		
306		0.05	IV	Cat	Chloralose and CO_2		
307	Ethalolguanidine HCl	5.0	SC	Rabbit	Urethane	40	+20
308	Ether (Diethyl)		Inhaled	Dog		24	+242
309	Ethinamate	1.5 g	Oral	Man		20	-5
310	6-Ethoxy-6-methoxy tetrahydro-isoquinoline	0.7-3.0	IV	Cat, dog	Anesthetized		0
311	6-Ethoxy-7-methoxy tetrahydro-isoquinoline	0.7-2.4	IV	Cat, dog	Anesthetized		-
312	2-Ethoxy	200	Oral	Cat		45	+18
313	phenanthrene	300	Oral	Cat		48	-8
314	3-Ethoxy	300	Oral	Cat		39	-10
315	phenanthrene	400	Oral	Cat			+8
316	6-Ethoxy tetrahydro-isoquinoline	0.6-2.1	IV	Cat, dog	Anesthetized		-
317	Ethyldihydro-	0.01-0.1	SC	Rabbit			-10
318	morphinone HCl	0.01-0.1	SC	Rabbit	8% CO_2		-9
319		0.2-0.5	SC	Rabbit			-41
320		0.2-0.5	SC	Rabbit	8% CO_2		-38
321		1.0	SC	Rabbit			-64
322		1.0	SC	Rabbit	8% CO_2		-65
323	Ethylguanidine HCl	10.0	SC	Rabbit	Urethane	168	+21
324	Ethylmorphine HCl	0.5-20.0	SC	Rabbit			-18(+2 to -23)
325		0.5-20.0	SC	Rabbit	8% CO_2		-14(0 to -32)
326	Glycerine	20%	Aerosol	Man		7	+133
327	Guanidine HCl	20	SC	Rabbit	Urethane		+8
328	Hexobarbital	60	IV	Dog		14	0
329	Histamine	1%	Aerosol	Man		7	-55
330	Hordenine sulfate	0.6-1.2	IV	Cat, dog	Anesthetized		0
331	l-3-Hydroxy-N-allyl-	0.0108	IV	Man			
332	morphinan	1.0-4.0	IV	Rabbit			
333		10.0	IV	Rabbit			
334	Hydroxycodeinone HCl	0.05-3.0	SC	Rabbit			+5(-0.5 to +14)
335		0.05-3.0	SC	Rabbit	6-10% CO_2		-1(+6 to -9)
336	l-3-Hydroxy-N-	0.054	IV	Man		10	-2
337	methylmorphinan	0.5-1.0	IV	Rabbit	Pentobarb.		
338	3-Hydroxy-N-methyl-	5 mg	IM	Man		11	-25
339	morphinan	5 mg	IM	Man	CO_2		-17
340	hydrobromide	7.5 mg	IM	Man			-6
341		7.5 mg	IM	Man	CO_2		-4
342		0.5	IV	Rabbit			-12
343		1.0	IV	Rabbit			-48
344		2.0	IV	Rabbit			-76
345		1.5-20.0	IV	Rabbit	Local anesth.		-83
346	2-Hydroxy phenanthrene	300	Oral	Cat		40	-8
347	3-Hydroxy phenanthrene	300	Oral	Cat		41	-3

/1/ Expired.

value (100%). Dose is expressed in mg/kg, unless otherwise indicated.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
							-16(-10 to -23)			52	293
							+1			52	294
							-14(-11 to -22)			52	295
671	+44	4.58	-8	3.35	-5					16	296
			+73				+32			53	297
							+37			52	298
							+90			52	299
							+23			52	300
							-15			52	301
							+13			52	302
							+134			52	303
							+67			52	304
		0.816	-48							54	305
		2.70	-15							54	306
										5	307
218	-31	5.25	+65			127	+27			56	308
										55	309
	0		0							44	310
	-		-							44	311
										2	312
										2	313
										2	314
										2	315
	-		-							44	316
			-6				+3(+2 to -7)			10	317
			-8							10	318
			-30				-7			10	319
			-44							10	320
			-50				-22			10	321
			-71							10	322
										5	323
			-6(+5 to -15)				+10(+3 to +15)			28	324
			-14(+5 to -33)							28	325
818	-34	5.20	+44				-20			15,16	326
										5	327
239	-23	3.34	-23							29	328
995	+67	5.53	-22	3.82	-8					16	329
	-		-							44	330
			-9							57	331
			-11							59	332
			+58							59	333
			+5				+13(+2 to +27)			4	334
			0							4	335
694	-31	6.6	-32							57	336
			-70							58	337
516	+7	5.5	-20					45[1]	+4[1]	60	338
	-30		-50						-9[1]	60	339
	+11		+2					68[1]	+15[1]	60	340
	-20		-35						+4[1]	60	341
			-28							61	342
			-48							61	343
			-63							61	344
										62	345
										2	346
										2	347

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate: Control breaths/min	Respiratory Rate: Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
348	6-Hydroxy-tetra-hydroisoquinoline	0.04-4.1	IV	Cat, dog	Anesthetized		-
349	Isocodeine acid tartrate	3.0-10.0	SC	Rabbit			-15
350		3.0-10.0	SC	Rabbit	CO_2		-16
351		15.0-50.0	SC	Rabbit			-50
352		15.0-50.0	SC	Rabbit	CO_2		-44
353	Isopropyl dihydro-morphinone HCl	0.05-0.2	SC	Rabbit			-13
354		0.05-0.2	SC	Rabbit	8% CO_2		-10
355		0.5-2.0	SC	Rabbit			-41
356		0.5-2.0	SC	Rabbit	8% CO_2		-41
357	Isopropylepinephrine	0.5-10.0%	Aerosol	Man		9	-62
358	5-Isopropyl-3-methyl-2-cyclohexen-1-one	200 mg	IM	Man			
359	Lobelin	0.1%	Aerosol	Man		9	-67
360		10 mg	SC	Man		17	+12
361	Meperidine HCl	100 mg	IV	Man			+15
362		150 mg	IV	Man		12	+8
363		75	SC	Dog		30	-60
364	Methadone	1.25 mg	SC	Man			
365		2.50 mg	SC	Man			
366		5.00 mg	SC	Man			
367		7.50 mg	SC	Man			
368	6-Methoxy-7-ethoxy-tetrahydro-isoquinoline	0.6-2.4	IV	Cat, dog	Anesthetized		-
369	Methoxymethyl-dihydromorphine HCl	0.05-1.0	SC	Rabbit			-5(+1 to -12)
370		0.05-1.0	SC	Rabbit	8% CO_2		-4(+2 to -11)
371		3.0-20.0	SC	Rabbit			-24
372		3.0-20.0	SC	Rabbit	8% CO_2		-24
373	2-Methoxy phenanthrene	200	Oral	Cat			-16
374		300	Oral	Cat			+3
375	3-Methoxy phenanthrene	300	Oral	Cat			-7
376		400	Oral	Cat			+3
377	6-Methoxy-tetrahydro-isoquinoline	0.6-5.3	IV	Cat, dog	Anesthetized		-
378	N-Methyl-6, 7-diethoxy tetrahydro-isoquinoline	0.5-1.4	IV	Cat, dog	Anesthetized		-
379	Methyldihydrocodeine HCl	0.3-10.0	SC	Rabbit			-1((+17 to -11)
380		0.3-10.0	SC	Rabbit	8% CO_2		-2(-10 to +8)
381	Methyldihydro-codeinone	0.3-5.0	SC	Rabbit			-19(-8 to -34)
382		0.3-5.0	SC	Rabbit	8% CO_2		-19
383		10.0	SC	Rabbit			-24
384		10.0	SC	Rabbit	8% CO_2		-20
385	Methyldihydro codeinone enol acetate	0.2	SC	Rabbit			-10
386		0.2	SC	Rabbit	8% CO_2		-4
387		0.5-10.0	SC	Rabbit			-23
388		0.5-10.0	SC	Rabbit	8% CO_2		-19
389	Methyldihydro-morphine HCl	0.2-5.0	SC	Rabbit			-17
390		0.2-5.0	SC	Rabbit	8% CO_2		-10
391		10.0-20.0	SC	Rabbit			-48
392		10.0-20.0	SC	Rabbit	8% CO_2		-42
393	Methyldihydro-morphinone HCl	4.0	SC	Dog		33	+12
394		0.01	SC	Rabbit			-4
395		0.01	SC	Rabbit	8% CO_2		-4
396		0.03-0.3	SC	Rabbit			-27
397		0.03-0.3	SC	Rabbit	8% CO_2		-21
398		0.5	SC	Rabbit			-52
399		0.5	SC	Rabbit	8% CO_2		-57
400		1.0	SC	Rabbit			-76
401		1.0	SC	Rabbit	8% CO_2		-78

MAN AND LABORATORY ANIMALS (Continued)
value (100%). Dose is expressed in mg/kg, unless otherwise indicated.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
	-		-							44	348
	-3(+4 to -8)		-18				-3(0 to -8)			7	349
	-4(+6 to -11)		-18							7	350
	+30		-36				-7(0 to -14)			7	351
	-6(0 to -11)		-45							7	352
			-2				+4(+9 to -5)			10	353
			-13							10	354
			-29				-13			10	355
			-48							10	356
663	+141	5.51	-23	3.85	-3					16	357
						234	+3			47	358
875	+43	7.87	-5							15	359
301	+18	5.12	+31							63	360
	-75		-75							65	361
519	-18	6.15	-10							66	362
										67	363
			+4							39	364
			+20							39	365
			+43							39	366
			-12							39	367
	-		-							44	368
			-3(+16 to -5)				+6			28	369
			-3(+4 to -17)							28	370
			-18				+5			28	371
			-25							28	372
										2	373
										2	374
										2	375
										2	376
	-		-							44	377
	-		-							44	378
			-1(+9 to -7)				+2(-3 to +7)			10	379
			-3(+15 to -12)							10	380
			-9				+2(-5 to +7)			10	381
			-21							10	382
			+2				+17			10	383
			+83							10	384
			-5				-1			10	385
			-6							10	386
			-16				0(+8 to -10)			10	387
			-22							10	388
			-5				+3			10	389
			-10							10	390
			-39				-16			10	391
			-47							10	392
										64	393
			0				+16			10	394
			-5							10	395
			-18				-4			10	396
			-23							10	397
			-41				-13			10	398
			-62							10	399
			-57				-29			10	400
			-76							10	401

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate Control breaths/min	Respiratory Rate Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
402	N-Methyl-5, 6-dihydroxy tetrahydroisoquinoline	0.6-3.5	IV	Cat, dog	Anesthetized		-
403	N-Methyl-6, 7-dihydroxy tetrahydroisoquinoline	0.05-3.8	IV	Cat, dog	Anesthetized		-
404	N-Methyl-5, 6-dimethoxy tetrahydroisoquinoline	0.7-3.9	IV	Cat, dog	Anesthetized		-
405	N-Methyl-6, 7-dimethoxy tetrahydroisoquinoline	0.7-3.9	IV	Cat, dog	Anesthetized		-
406	N-Methyl-5-ethoxy-6-methoxy tetrahydroisoquinoline	0.7-1.3	IV	Cat, dog	Anesthetized		-
407	N-Methyl-6-ethoxy-7-methoxy tetrahydroisoquinoline	0.9-1.3	IV	Cat, dog	Anesthetized		-
408	Methylguanidine HCl	5.0	SC	Rabbit	Urethane	66	+9
409	N-Methyl-6-hydroxy tetrahydroisoquinoline	0.6-3.2	IV	Cat, dog	Anesthetized		-
410	N-Methyl-6-methoxy-7-ethoxy tetrahydroisoquinoline	0.9-1.5	IV	Cat, dog	Anesthetized		-
411	N-Methyl-6-methoxy-tetrahydroisoquinoline	0.6-3.5	IV	Cat, dog	Anesthetized		-
412	N-Methyl-tetrahydroisoquinoline	0.5-9.5	IV	Cat, dog	Anesthetized		-
413	Monoacetyl-dihydromorphine HCl	0.1-1.0	SC	Rabbit			-34
414		0.1-1.0	SC	Rabbit	CO_2		-27
415		2.0-10.0	SC	Rabbit			-76
416		2.0-10.0	SC	Rabbit	CO_2		-78
417	Monoacetyl-α-isomorphine HCl	0.0005-0.01	SC	Rabbit			-5
418		0.0005-0.01	SC	Rabbit	8% CO_2		+4
419		0.02-0.05	SC	Rabbit			-14
420		0.02-0.05	SC	Rabbit	8% CO_2		-11
421		0.1-0.2	SC	Rabbit			-42
422		0.1-0.2	SC	Rabbit	8% CO_2		-37
423		0.5-2.0	SC	Rabbit			-67
424		0.5-2.0	SC	Rabbit	8% CO_2		-71
425	Monoacetyl-morphine HCl	0.01-0.3	SC	Rabbit			-31
426		0.01-0.3	SC	Rabbit	CO_2		-23
427		0.5-10.0	SC	Rabbit			-82
428		0.5-10.0	SC	Rabbit	CO_2		-85
429	Morphine sulfate	16.2 mg	Oral	Man			
430		10.0 mg	SC	Man			
431		10.0 mg	SC	Man	CO_2		
432		0.5	IV	Man			-33
433		10.0 mg	IV	Man			-9(-1 to -15)
434		10.0 mg	IV	Man	CO_2		
435		15.0 mg	IV	Man	5% CO_2		
436		15.0-60.0 mg	IV	Man			-2(+4 to -5)
437		75.0-90.0 mg	IV	Man			-17
438		5.0	IV	Rat			-47
439		6.0	IV	Rabbit	Anesthetized		
440		4.0-32.0	IV	Rabbit			-60
441		0.5	IV	Rabbit			
442		5.0-40.0	SC	Rabbit			-79
443		0.1-0.5	SC	Rabbit			-9
444		0.1-0.5	SC	Rabbit	CO_2		-11

/1/ Alveolar. /2/ Arterial.

MAN AND LABORATORY ANIMALS (Continued)
value (100%). Dose is expressed in mg/kg, unless otherwise indicated.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
	-		-							44	402
	-		-							44	403
	-		-							44	404
	-		-							44	405
	-		0							44	406
	-		-							44	407
										5	408
	0		-							44	409
	-		0							44	410
	-		-							44	411
	-		-							44	412
	+24		-20				-2			45	413
	-3		-28							45	414
	+74		-66				-24			45	415
	0(+26 to -27)		-81							45	416
			+3				+1			3	417
			+8							3	418
			-9				+1			3	419
			-11							3	420
			-30				-12			3	421
			-39							3	422
			-57				-17			3	423
			-76							3	424
	+22		-18				-2			45	425
	0		-23							45	426
	+79		-70				-11(+19 to -31)			45	427
	+8		-84							45	428
			-18				-5			14	429
			-23							40,42	430
			-23							42	431
			-28							31	432
	-19		-9							65,66	433
	-30		-20						+7[1]	23,65	434
			-27							23	435
	-14		-18(-1 to -28)		-23(+1 to -36)		-3(+10 to -7)		+10[2]	21	436
	-13		-35		-40		-6		+20[2]	21	437
			-60							70	438
			-68							58	439
			-54							59,61	440
			-20							69	441
	+61		-73							6,14	442
	+5		-6				+6			41	443
	+1		-10							41	444

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate	
						Control breaths/min	Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
445	Morphine sulfate	0.75-3.0	SC	Rabbit			-43
446	(concluded)	0.75-3.0	SC	Rabbit	CO_2		-42
447		5.0-10.0	SC	Rabbit			-55
448		5.0-10.0	SC	Rabbit	CO_2		-63
449	Nalorphine HCl	1.0-5.0 mg	IV	Man			-10
450		10.0 mg	IV	Man			-3(+12 to -18)
451		5.0 mg	IV	Man	5% CO_2		
452		2.0 mg	IV	Man		11	-6
453		2.0 mg	IV	Man	100% O_2	12	-5
454		2.0 mg	IV	Man	2.8% CO_2	13	-1
455		2.0 mg	IV	Man	4.3% CO_2	15	-9
456		30.0	IV	Dog	Pentobarb.		+80
457	Neutral red	0.1	IV	Rabbit	Pentobarb.		+1
458	(2-Methyl, 3-amino,	0.5	IV	Rabbit	and		+41
459	6-dimethylamino-phenazine HCl	1.0-10.0	IV	Rabbit	urethane		+37
460	Neutral violet	0.1-2.0	IV	Rabbit	Pentobarb.		+4
461	(2-Dimethylanilino, amino, 3-amino, 6-dimethyl amino-phenazine HCl	5.0-10.0	IV	Rabbit	and urethane		-5(+7 to -16)
462	Nikethamide	250.0 mg	SC	Man			
463		7.5	IM	Man	Morphine		+26
464	Norepinephrine	20 μg	IV	Man			
465	β-Oxybutyrate sodium	10 cc 0.10 N	IV	Rabbit	Urethane		+1
466	β-Oxybutyric acid	20 cc 0.15 N	IV	Rabbit	Urethane		+28
467		10 cc 0.10 N	IV	Rabbit	Urethane		+18
468		20 cc 0.10 N	IV	Rabbit	Urethane		+22
469	Oxygen	100%	Inhaled	Man			+7
470		33%	Inhaled	Man			
471		8-100%	Inhaled	Man			-
472	Papaverine HCl	0.4-1.0	IV	Cat, dog	Anesthetized		±
473	Pentobarbital sodium	10.0	IP	R. monkey		43	-5
474		30.0	IV	Dog			
475		35.0	IP	Cat	2% CO_2		-38
476		35.0	IP	Cat	4-8% CO_2		-37
477		200	SC	Rabbit			-56
478		5.0	IV	Rabbit fetus			-54
479		10.0	IV	Rabbit fetus			-62
480	Pentylenetetrazol	7-100 mg	SC	Man			
481		100 mg	SC	Man			
482		10%	Aerosol	Man			+150
483		5.0	IM	Man	Morphine		+50
484		5.0-7.0	IV	Dog	Alcohol		+4500
485	Peptone	20%	Aerosol	Man			+59
486	Phenobarbital	3.1-8.0	Oral	Man		10	+6
487	Phenyldihydro-	0.01-0.05	SC	Rabbit			-7
488	morphinone HCl	0.01-0.05	SC	Rabbit	8% CO_2		-1
489		0.1-0.2	SC	Rabbit			-13
490		0.1-0.2	SC	Rabbit	8% CO_2		-16
491		0.5-1.0	SC	Rabbit			-45
492		0.5-1.0	SC	Rabbit	8% CO_2		-42
493		2.0	SC	Rabbit			-72
494		2.0	SC	Rabbit	8% CO_2		-73
495	Phenyl-methyl-aminopropane	5%	Aerosol	Man		6	-61
496	Phosgene	1.38 mg	IV	R. monkey			-23

/1/ Arterial. /2/ Alveolar.

MAN AND LABORATORY ANIMALS (Continued)
value (100%). Dose is expressed in mg/kg, unless otherwise indicated.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
	+23		-32				0			41	445
	+1		-41							41	446
	+20		-46				-9			41	447
	-20		-70							41	448
	-30		-28		-32		+33		+6[1]	21	449
	-36(-15 to -58)		-45(-48 to -42)		-44		+54		+14[1]	21,22	450
			-25							23	451
552	+3	6.3	-3							24	452
520	+2	6.3	-3							24	453
1031	-25	13.1	-26							24	454
1246	-25	18.7	-31							24	455
	-5		+160				+27			25	456
	0									17	457
	+3									17	458
	-22									17	459
	+5									17	460
	+8(-6 to +17)									17	461
							+1			47	462
	+10		+38							31	463
			+49				+8			53	464
	+2		+4						-2[1]	1	465
	+35		+80						-10[1]	1	466
	+21		+43						-10[1]	1	467
	+46		+79						+6[1]	1	468
	+10		+12(+7 to +16)						+1[1]	36,71,72	469
			-8						+1[2]	73	470
			+							74	471
	±		±							44	472
60	-5	2.64	-10							75	473
									+47[1]	76	474
	-17		-48							37	475
	-49		-68							37	476
	+42		-38							6	477
										77	478
										77	479
			-7							39	480
						264	-5			47	481
	+106		+415							15	482
	-16		+26							31	483
										68	484
	-34		+5							15	485
							+4(-7 to +14)			11	486
			-3				-0.5			10	487
			0							10	488
			-4				+6			10	489
			-16							10	490
			-32				-5			10	491
			-45							10	492
			-56				-26			10	493
			-76							10	494
713	+129	4.48	-14	2.85	+14					16	495
	-33		-51							75	496

Drug response is expressed in % increase or decrease from the control

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate: Control breaths/min	Respiratory Rate: Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
497	Picrotoxin	0.3	IV	Dog	Phenobarb.		-13
498		0.6	IV	Cat	Phenobarb.		+6
499		0.7	IV	Cat	Phenobarb. and morphine		+10
500		0.7	IV	Cat	Chlorbutanol		+7
501	Pilocarpine	5.3%	Aerosol	Man		53	+190
502	Ac-2, 2-Piperidino methyltetra-hydro-naphthol HCl	100	SC	Rabbit		44	+27
503	Piperidione	105 mg	Oral	Man			
504	Piperoxan HCl	20%	Aerosol	Man		8.5	+76
505	(F-933)	0.1-30%	Aerosol	Man		9.5	-9
506	Placebo	2 cc	IV	Man		12	+9
507		2 cc	IV	Man			
508		2 cc	SC	Man			
509		2 cc	SC	Man	5% CO_2		
510		H_2O	Aerosol	Man			+16
511	Prisilidene HCl	60 mg	SC	Man			-15
512	Probarbital sodium	100 mg	Oral	Man			+37
513		200 mg	Oral	Man			+12
514		300 mg	Oral	Man			-11
515		400 mg	Oral	Man			+18
516	Procaine	1%	Aerosol	Man		6	-58
517		2%	Aerosol	Man		6	-29
518	Pseudocodeine HCl	20.0-40.0	SC	Rabbit			0
519		20.0-40.0	SC	Rabbit	CO_2		+4
520		60.0-80.0	SC	Rabbit			-4
521		60.0-80.0	SC	Rabbit	CO_2		-4
522		100.0-300.0	SC	Rabbit			-15
523		100.0-300.0	SC	Rabbit	CO_2		-20
524	Pyribenzamine	10 mg	IV	Dog	Pentobarb.		+60
525		100 mg	IV	Dog	Pentobarb.		
526	Pyruvic acid cyanohydrin	0.15 cc 0.1 M/kg	IV	Dog	Pentobarb.		+48
527		0.15 cc 0.1 M/kg	IV	Cat	Phenobarb.		+50
528	Scopolamine	0.65 mg	Oral	Man			
529	Seconal sodium	300 mg	Oral	Man		20	-3
530	Sodium acetate	10 cc 0.1 N	IV	Rabbit	Urethane		0
531	Sodium nitrite	1-10%	Aerosol	Man			-41
532	Sodium phosphate	10%	Aerosol	Man		13	-35
533	Sodium salicylate	2 g	IV	Man		8	+1
534		2 g	IV	Man	3-5% CO_2		+12
535		3 g	Oral	Man			+17
536		3 g	Oral	Man	3-5% CO_2		+30
537		100 g	IV	Dog	Pentobarb.	10	+25
538	Strychnine nitrate	1-2 mg	SC	Man			
539	Tetrahydro-isoquinoline HCl	0.55-4.8	IV	Cat, dog	Anesthetized		-
540	Thiopental	500 mg	IV	Dog			
541		20-30	IV	Dog			-45
542		40	IV	Dog			-80
543		100	IV	Monkey			+76
544		20	IV	Cat			-82
545		20	IV	Rabbit			-75
546	Tribromoethanol	710 mg	Rectal	Rabbit			-50
547	Trichloroacetaldehyde	500-1000	SC	Rabbit			-19
548	Triphenylguanidine HCl	2	SC	Rabbit	Urethane		+9

/1/ Arterial. /2/ Alveolar.

MAN AND LABORATORY ANIMALS (Continued)
value (100%). Dose is expressed in mg/kg, unless otherwise indicated.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
	+15		+1							79	497
	+24		+32							79	498
	+23		+35							79	499
	+59		+70							79	500
821	-47	4.28	+44	3.07	+7					16	501
13	-8	0.576	+16			32	+50			46	502
	-7									39	503
900	-9	7.65	+62							15	504
661	+32	6.22	-5	4.36	-2					16	505
	-9		+1.5(+1 to +2)							23,66	506
			-3							40	507
			-1							42	508
			-5							42	509
	-11		-2		-3					16	510
	-30		-35							65	511
							-8			11	512
							+2			11	513
							-16			11	514
							-6			11	515
725	+52	4.35	-37							15	516
848	+104	4.62	-20	3.25	-7					16	517
	-1		-1				-2			7	518
	+1		+5							7	519
	-3		-6				+5			7	520
	0		-4							7	521
	-2		-18				-7			7	522
	-13		-32							7	523
	-14		+37							26	524
			+82							26	525
	+13		+66							80	526
	+48		+120							80	527
			+14				+2			14	528
										55	529
	-5		-4						0[1]	1	530
	+56		-15		+2					15,16	531
	+74		+13							15	532
		6.33	+15	239	+10			40.9[2]	-5[2]	81	533
			+15						-4[2]	81	534
			+18						-7[2]	81	535
			+25						-7[2]	81	536
		2.01	+65	127	+70				-8[1]	81	537
				245	0					47	538
	0		-							44	539
					-42				+29[2]	82	540
										83	541
										83	542
										83	543
										83	544
										83	545
										33	546
			-16							6	547
										5	548

Drug response is expressed in % increase or decrease from the control

	Drug	Dose	Mode of Administration	Species	Premedication	Respiratory Rate	
						Control breaths/min	Drug %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
549	d-Tubocurarine	0.23	IV	Man	Cyclopropane		
550		0.11	IV	Man	Ether		
551	Urethane	1000	IP	Cat			0
552		1000	IP	Cat	2-8% CO_2		+9(+6 to +15)

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MAN AND LABORATORY ANIMALS (Concluded)

value (100%). Dose is expressed in mg/kg, unless otherwise indicated.

Tidal Volume		Minute Volume		Alveolar Ventilation		O_2 Consumption		pCO_2		Reference	
Control cc	Drug %	Control L/min	Drug %	Control L/min	Drug %	Control cc/min	Drug %	Control mm Hg	Drug %		
(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	
			-70							78	549
			-70							78	550
	-13		-13							37	551
			-15							37	552

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132. RESPIRATORY ACTION OF DRUGS INFLUENCING AFFERENT END-ORGANS: CAT, DOG, RABBIT

Drugs influencing baroreceptors have not been included in this table.

i.v. = intravenous; i.c.a. = intracarotid artery; i.c.b.a. = intracarotid-body artery; rt.at. = right atrium.

	Drug Group	Drug	Test Animal	Dose and Route	End-organ Response	Respiratory Response	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Drugs Influencing Carotid-body Chemoreceptors						
1	Ganglionic stimulants	Nicotine[1]	Dog	0.1-0.2 mg i.c.a.		Stimulation	1
2			Cat	0.1 mg i.v.	Stimulation		2
3		Lobeline	Dog	0.5 mg i.c.a.		Stimulation	1
4			Cat	1 mg i.v.	Stimulation		2
5		Acetylcholine[2]	Dog	0.1-0.5 mg i.c.a.		Stimulation	3
6			Cat	2-10 µg i.c.b.a.	Stimulation		4, 5
7	Metabolic inhibitors and stimulants	Potassium cyanide	Dog	1-2 mg i.c.a.		Stimulation	1
8			Cat	0.02% infused i.v.	Stimulation	Stimulation	2
9		Sodium sulfide	Dog	1-2 mg i.c.a.		Stimulation	1
10		2,4-Dinitrophenol[3]	Dog	0.4 mg i.c.a.		Stimulation	6
11			Cat	0.4 mg i.c.a.	Stimulation		7
12		Mono-iodoacetic acid	Dog	3-7 x 10^{-4}% perfused[4]		Stimulation	8
13		Sodium mono-iodo-acetate	Cat	2.0 mg i.c.a.	Stimulation		4
14		Adenosine triphosphate	Dog, cat	1-10 mg i.c.a.	Stimulation		7
15	Ions	Potassium (chloride)	Dog, cat	1.2-10 mg i.v.		Stimulation	9, 10
16			Cat	20-200 µg i.c.a.	Stimulation	Stimulation	7
17		Citrate (sodium)	Cat	12.5-25 mg i.c.a.	Stimulation	Stimulation	7
18	Veratrum alkaloids	Veratridine[5]	Dog	1-2 µg i.c.a.		Stimulation	11
19		Veratrine	Cat	10-40 µg i.c.a.	Stimulation		7
20	Anticholinesterases	Eserine salicylate[6]	Cat	50-500 µg i.c.a.	Stimulation		12
21		Neostigmine HCl	Dog	0.1-1 mg locally		Stimulation	13
22			Cat	0.25 mg i.c.a.	Stimulation		12
23		Tetra-ethylpyro PO_4	Cat	0.2 mg i.c.a.	Stimulation		12
24		Diisopropoxyphosphonyl-fluoride	Cat	0.1 mg i.c.a.	Stimulation		12
25	Miscellaneous	Caffeine[7]	Cat	1.8 mg i.c.b.a.	Stimulation		4
26		Coniine[8]	Cat	0.05 mg i.v.		Stimulation	14
27		Ethyl alcohol[9]	Cat	18-76 mg i.c.a.	Stimulation		15
28		Homo-isomuscarine[10]	Dog	10 mg/kg i.v.		Stimulation	16
29		5-Hydroxytryptamine[11]	Dog	50-100 µg i.v.		Stimulation	17
30		Isolobinine	Dog	10 µg/kg i.v.		Stimulation	18
31		Papaverine	Cat, dog	0.25-1 mg i.c.a.		Stimulation	19
32		Phenyl diguanide[12]	Dog	10 µg/kg iv	Stimulation	Stimulation	20
33		Piperidine HCl	Cat	0.3-1 mg i.v.	Stimulation	Stimulation	21
34		Tetramethylammonium iodide[13]	Cat	1:10,000 perfused[4]		Stimulation	14
35		Tetra-ethylammonium chloride	Cat	0.5-1.0 mg i.c.a.	Sensitization		22
36		Hexamethonium	Cat	0.25-0.5 mg i.c.a.			22
37		Pendiomide[14]	Cat	0.25-0.5 mg i.c.a.			22
38		Pentamethonium	Cat	0.25-0.5 mg i.c.a.			22
	Drugs Influencing Pulmonary Stretch Receptors[15]						
39	Veratrum alkaloids	Veratrine	Rabbit	50-100 µg/kg	Stimulation		23
40		Veratridine	Cat	5-10 µg/kg i.v.	Stimulation	Apnea	24
41		Germitrine, germerine, and neogermitrine	Cat	26-400 µg i.v.	Stimulation		25
42		Veriloid	Cat, dog	10-20 µg/kg i.v.	Stimulation	Apnea	26
43	Volatile anesthetics	Trichlorethylene	Cat	0.5-2% inhaled[16]	Sensitization[17]	Rapid, shallow	27
44		Chloroform	Cat	1% inhaled			27
45		Ethyl ether	Cat	10% inhaled			27
46		Divinyl ether	Cat	4% inhaled	Sensitization[17]		27

/1/ Also α- and β-nicotine, 0.1-0.3 mg i.c.a. in dogs, and other nicotine derivatives [33,34]. /2/ Also many other choline derivatives [5,35-37]. /3/ Also 2,4-dinitrocresol and p-nitrophenol, 0.4 mg i.c.a. in dogs [6]. /4/ Isolated perfused carotid sinuses and bodies. /5/ Doses possibly excessive [43]. /6/ Somewhat controversial [13]. /7/ Probably also theophylline (1.5 mg i.c.b.a.) and theobromine (1 mg i.c.b.a.) in cats [4]. /8/ Also cytisine (0.2 mg i.v.) and anabasine in cats [14]. /9/ Also acetone, ethyl ether and chloroform, and various alcohols [15]. /10/ Also acetylsalicylamide and many derivatives of both substances [16,38]. /11/ Creatinine SO_4; controversial [39]. /12/ Also 2-α-naphthyl ethyl isothiourea; controversial [40]. /13/ Also various derivatives [35,41,42]. /4/ Tris(diethylaminoethyl)amine tri HCl. /15/ Slowly adapting receptors mediating the "Hering-Breuer inflation reflex." /16/ Also i.v. in unspecified dose. /17/ Greater concentrations cause inhibition.

132. RESPIRATORY ACTION OF DRUGS INFLUENCING AFFERENT END-ORGANS: CAT, DOG, RABBIT (Concluded)

Drugs influencing baroreceptors have not been included in this table.

i.v. = intravenous; i.c.a. = intracarotid artery; i.c.b.a. = intracarotid-body artery; rt.at. = right atrium.

	Drug Group	Drug	Test Animal	Dose and Route	End-organ Response	Respiratory Response	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Drugs Influencing Pulmonary Stretch Receptors (Concluded)[15]						
47	Volatile anesthetics (concluded)	Cyclopropane	Cat	50% inhaled	Sensitization	Slow, shallow	27
48		Nitrous oxide	Cat	80% inhaled	Sensitization		27
49	Local anesthetics	Novocaine	Rabbit	20-100 mg/kg i.v.	Inhibition	Inspiration prolonged	28
50		Diphenhydramine HCl	Cat, dog	6 mg/kg i.v.	Inhibition		29
	Drugs Influencing Pulmonary Deflation Receptors[18]						
51	Miscellaneous	Phenyl diguanide[19]	Cat	50-100 µg/kg rt.at.	Sensitization	Apnea or rapid, shallow	24, 30
52		Nicotine[20]	Cat	25-100 µg/kg rt.at.			30
53		5-Hydroxytryptamine[21]	Cat	1-50 µg/kg rt.at.			30, 31
54		Urethane	Cat	225 mg rt.at.	Sensitization		30
55		Acetylcholine	Cat	175 µg rt.at.	Sensitization		30
56		2, α-Naphthyl ethyl isothiourea[22, 23]	Cat, rabbit	4-60 µg/kg i.v.		Apnea followed by rapid, shallow	24
57		Veratridine[23]	Rabbit	5-10 µg/kg i.v.			24
58		Diphenhydramine HCl[23, 24]	Cat, dog, rabbit	0.4-3 mg/kg i.v.			29, 32
59		Mepyramine maleate[23]	Cat, dog, rabbit	5-10 mg/kg i.v.			29, 32

/15/ Slowly adapting receptors mediating the "Hering-Breuer inflation reflex." /18/ Possibly responsible for the "Hering-Breuer deflation reflex" and the "pulmonary respiratory chemo-reflex"; this has not been established [43]. /19/ Probably also 18 other guanides [44]. /20/ Sulphate. /21/ Creatinine SO_4. /22/ Also 13 other isothioureas. /23/ Not established by nervous action-potential records. /24/ Also 20 similar substances in dogs.

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Drugs are listed alphabetically, using a well-known name. Inclusion of trade names is for informative purposes only and in no way implies endorsement by The National Academy of Sciences-The National Research Council. For all "effects" included in this table, there is reasonable evidence the drug in fact acted on the bronchial musculature. Where there was evidence that an effect was mediated by the respiratory center or adrenal glands, it was excluded. Drug actions influencing only anaphylactic or asthmatic bronchospasm, or other pathological states of the bronchi, were also excluded. Concentrations of drugs are given in μg/ml for local action on isolated preparations, and doses in mg/kg for drugs administered systemically. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted. A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive.

	Compound (Synonym)	Species	Effect: Local μg/ml	Effect: Local Action	Effect: Systemic mg/kg	Effect: Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Acacia (Gum arabic)	Guinea pig	17,000	I			1
2	Acetic acid	Dog		D[1]			2
3	Acetylcholine	Man	0.2-40	C			3-28
4		Cat	0.1-10	C	0.002-1.0	C	
5		Dog	0.01-1.0	C	0.002-0.5	C	
6		Guinea pig	0.1-200	C	0.01-0.05	C	
7		Monkey	4-40				
8		Ox	0.7	C			
9		Pig		C			
10		Rabbit	0.5-10	C			
11		Rat	1-10	C			
12		Frog	10^{-6}-100	C			
13	Acetylmorphine	Dog				C	29
14	Aconitine	Frog	300	C	0.1-1.0	C	30
15		Turtle				C	
16	Adenine (6-Aminopurine)	Guinea pig	10-100	D			15,31
17		Pig	<1	D			
18	Adenosine (9-Adenine ribofuranoside)	Cat			5	D	15,32
19		Guinea pig	10-100	D	1	D	
20	Adenosine triphosphate	Cat				I	15,33
21		Guinea pig	200-400	D			
22	Adenylic acid, muscle (Adenosine-5-	Cat			10	(D)	15,34
23	phosphoric acid)	Guinea pig	10-200	D			
24	Adenylic acid, yeast (Adenosine-3-	Cat			10	I	15,32,34
25	phosphoric acid)	Guinea pig	<400	I		D	
26	Agar	Guinea pig	10,000	C	15-50	C	1,35,36
27	Agaricin	Dog				(D)	37
28	Agmatine	Guinea pig		C			38
29	Alcohol (Ethanol)	Cat			500	D	31,39,40
30		Ox		A			
31		Pig		D			
32	Allantoin	Guinea pig	1-20	I			15
33	Alloxan (2,4,5,6-Tetraoxopyrimidine)	Guinea pig	20-40	D			15
34	Alphaprodine (Nisentil; Nu-1196; α-1,3-Dimethyl-4-phenyl-4-propionoxy-piperidine)	Guinea pig		I			41
35	Alstonine (Chlorogenine)	Dog			3-5	D	42
36	Althea	Guinea pig	25,000	I			1
37	Alypin	Pig		D			31
38	Aminophylline (Theophylline-ethylenediamine)	Man	10-100	D	4-10	D	17,21,43-53
39		Cat	1000	D			
40		Dog	100-500	D	12-75	D	
41		Guinea pig	5-200	D	50-100	D	
42		Rabbit	1,000-10,000	D			
43		Rat	100	D			
44	2-Aminopyrimidine	Guinea pig	10-100	D			15
45	Aminopyrine (Pyramidon)	Guinea pig	1000	D			54
46	Ammonium bicarbonate	Rabbit			25	I	55
47	Ammonium chloride	Ox	1500	D			10,31,39,55
48		Pig	800	C			

/1/ At pH 6.

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect				Reference
			Local		Systemic		
			µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
49	Ammonium chloride (concluded)	Rabbit			50	D	10,31,39,55
50		Frog	300-1000	C			
51	Amyl nitrite	Guinea pig	5000	D			56
52	Anagyrine	Guinea pig	50-100	(C)			16
53	Andromedotoxin	Guinea pig	20	C			57,58
54		Rabbit	1-4	C			
55	Antazoline (Antistine; Histostab; N-Benzyl-N-phenyl-aminomethylimidazoline)	Man	800	D			59,60
56		Cat			5	C	
57		Guinea pig	5-40	C			
58		Guinea pig	100-1000	D			
59	Antergan (Lergitin; RP2339; N-Benzyl-N-phenyl-N', N'-dimethyl-ethylenediamine)	Cat			0.5-5.0	C	59-61
60		Dog			1.0	C	
61	Antipyrine (Phenazone; 1,5-Dimethyl-2-phenyl-3-pyrazolone)	Pig		C			31
62	Apocodeine	Cat			1	C	62
63		Rabbit			1	C	
64	Apothesin	Pig		I			31
65	Arecoline	Cat	0.3-2.5	C	0.02-3.0	C	5,12,19,39, 63-71
66		Dog		C	0.02-0.5	C	
67		Guinea pig	1	C			
68		Ox	1-170	C			
69		Rabbit		C	0.1-0.45	C	
70	Arsphenamine	Guinea pig	100-200	I			1
71	Aspidiospermine	Cat				I	72
72		Ox		I			
73	Aspidiosamine	Cat				I	72
74		Ox		I			
75	Atropine	Man	<10	I			6,8,10,24, 26,36,37, 39,43,56, 60,64,68, 73-77
76		Cat		D			
77		Dog	5	(D)	<2	I	
78		Guinea pig	<10	I			
79		Guinea pig	100-1000	C			
80		Monkey		C			
81		Ox	30	D			
82		Rabbit		D			
83		Rat		D			
84		Frog	10-20	D			
85	Azapetine (Ilidar; Ro Z-3248; 6-Allyl-6,7-dihydro-5H-dibenz-[c,e]-azepine)	Guinea pig	10	C			78
86	Barbituric acid	Guinea pig	10	(D)			15
87	Barium chloride	Man		C			10,15,31,36, 39,43,56, 77,79-85
88		Cat		C	10-100	C	
89		Dog	50	C	3-20	C	
90		Guinea pig	20-5000	C			
91		Ox	10-30	C			
92		Pig	800	C			
93		Rabbit	30-3000	C			
94		Sheep		C			
95		Frog	25-2500	C			
96	Benzoylcholine	Cat	<1000	I			86
97		Rabbit	<1000	I			
98	Benzyl acetate	Pig	5000	D			31
99	Benzyl alcohol	Pig	400-800	D			31
100	Benzyl benzoate	Dog				(C)	31,87,88
101		Pig		D			
102	1-Benzyl-3-β-diethylaminoethyl-5,5-diallyl barbituric acid	Cat			6-10	C	61
103	Benzyl nitrite	Pig	400	D			31
104	Benzylmorphine (Peronine)	Dog			2	C	29
105	Benzyltrimethylammonium iodide	Guinea pig		C			89
106	Betaine hydrazide	Dog				C	90
107	Bradykynin (Kallidin)	Man		I			15,91

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect: Local µg/ml	Effect: Local Action	Effect: Systemic mg/kg	Effect: Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
108	Bradykynin (Kallidin) (concluded)	Cat		I			15,91
109		Guinea pig	1-100	C			
110	Bromal hydrate	Dog			20	C	92
111	γ-Bromohomocholine bromide (γ-Bromopropyltrimethylammonium bromide)	Dog				C	93
112	Cadaverine	Guinea pig		C			38
113	Caffeine (Theine; Trimethylxanthine)	Cat		D		D	10,15,37,39, 56,84,95, 96
114		Dog				D	
115		Guinea pig	20-1000	D	10-1000	D	
116		Ox	1000	D			
117		Pig	400	D			
118		Frog	400	D			
119	Calcium chloride	Guinea pig	5000	C			10,36,39,97
120		Ox	5000	C			
121		Frog	800	C			
122	Camphor[1]	Ox	100-500	D			98
123			1000	C			
124	Caramiphen (Parpanit; Diethylaminoethyl 1-phenyl-cyclopentyl-1-carboxylate)	Guinea pig		(C)			99
125	Carbachol (Doryl; Carbaminoylcholine)	Man	0.1-1	C			17,20
126		Guinea pig	5-50	C			
127	Carbaminoyl-β-methylcholine	Cat			0.2-2.0	C	100
128		Guinea pig		C			
129	Chelidonine	Cat			5-10	D	31,101-103
130		Dog			5-10	D	
131		Guinea pig		D			
132		Pig	800	D			
133		Rabbit			50	D	
134	Chlorcyclizine (Di-Paralene, Histantin;	Cat			2-10	C	60
135	Perazil; 47-282; N-(4-Chlorbenzhydryl)-N'-	Guinea pig	5-100	C			
136	methyl-piperazine)	Guinea pig	100-1000	D			
137	Chloral hydrate	Dog				I	39,92
138		Ox	100	A			
139	Chloroform	Guinea pig	3000	D			2,31,39,56, 104
140		Ox		C			
141		Pig		A			
142	Chloroguanide (Guanatol; Paludrine; Proguanil; N_1-(p-Chlorophenyl)-N_5-isopropyl-biguanide)	Guinea pig			0.5-10	I	105
143	Chlorothen (Chloropyrilene; Tagathen;	Cat			3	(C)	60
144	N-(5-Chloro-2-thenyl)-N-(2-pyridyl)-	Dog			5	C	
145	N', N'-dimethyl-ethylenediamine)	Guinea pig	1-160	C			
146		Guinea pig	200-1000	D			
147	Chlorpheniramine (Chlorprophenpyridamine;	Cat			10	C	60
148	Chlor-Trimeton; 1-(p-Chlorophenyl)-1-	Guinea pig	1-400	C			
149	(2-pyridyl)-3-dimethylamino-propane)	Guinea pig	1000	D			
150	Choline chloride	Dog				(D)	16,37,56, 106,107
151		Guinea pig	10-1000	C			
152		Rabbit		(C)	50	C	
153	Choline ethyl ether	Cat				(C)	7
154	Choline nitrate	Cat				(C)	7
155	Choline nitrite	Cat				(C)	39
156		Ox	>1	C			
157	Citrinin	Guinea pig		C			108
158	Clupeine	Guinea pig		C			38
159	Cocaine	Cat		C			30,31,37, 39,68
160		Dog		C		I	
161		Ox	1000	D			
162		Pig		D			
163		Rabbit		C			

/1/ See also sodium camphorate.

133. DIRECT ACTION OF DRUGS ON THE BRONCHI (Continued)

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym) (A)	Species (B)	Effect: Local µg/ml (C)	Effect: Local Action (D)	Effect: Systemic mg/kg (E)	Effect: Systemic Action (F)	Reference (G)
164	Cocaine (concluded)	Frog	100-1000	C	0.5-5	C	30,31,37, 39,68
165		Turtle			0.5-5	(D)	
166	Codeine (Methyl morphine)	Dog		(C)			29,31,79, 109,110
167		Pig		(C)			
168	Colchiceine	Pig		(D)			31
169	Colchicine	Pig		(D)			31
170	Compound 48/80 ((p-Methoxyphenylethyl)-methylamine formaldehyde polymers)	Guinea pig	40	C			111
171	Congo red	Guinea pig	1000	I			1
172	Coniine	Guinea pig	10-100	C			16
173	Cotarnine (Stypticine)	Dog				(D)	29,66
174	Creatinine	Guinea pig	10-100	I			15
175	Cryptopeine (Cryptopine)	Dog				I	29,109
176		Pig		I			
177	Cularine	Guinea pig	20-200	I			112
178	Curare[1]	Cat				A	62,80,96, 114,115
179		Dog				C	
180		Guinea pig				C	
181		Rabbit				C	
182	Curarine	Cat	300-600	C			114,116,117
183		Dog			0.5-2.0	C	
184		Guinea pig				C	
185	Cyanuric acid (s-Triazinetriol)	Guinea pig	10-100	(D)			15
186	Cytisine	Guinea pig	50-200	C			16
187	Darmstoff	Ox		I			118
188	Decamethonium (Eulissin)	Man	10	(D)			15
189	2, 6-Diaminopurine	Guinea pig	20-80	D			15
190	Dextrin	Guinea pig	10,000	I			1
191	Dextromethorphan (Ro 1-5470/5; d-3-Methoxy-N-methyl-morphinan)	Cat			1	C	119
192	Dextrorphan (Ro 1-6794; d-3-Hydroxy-N-methyl-morphinan)	Cat			1	C	119
193	Dibenzyline (Dibenyline; SKF 688; N-Phenoxy-isopropyl-N-benzyl-β-chloroethylamine)	Guinea pig	1-10	I			16
194	Dicholine chloride (Di-trimethyl ethylenediamine dichloride)	Rabbit		C			107
195	Diethylaminoethanol	Guinea pig		C			120
196	Diethylaminoethyl diphenylhydroxythioacetate (Ro 3-0226)	Guinea pig	3-5	D			83,121
197	Diethylaminoethyl diphenylthioacetate (Ro 3-0235)	Guinea pig	10-30	(D)			83
198	2-(2'-Diethylaminoethylthio)-1, 1-diphenyl-	Guinea pig	10-30	D			83,121
199	ethanol (Ro 3-0326)	Rabbit	1-5	(D)			
200	Diethylmorphine	Cat		C			68,76
201		Dog		C	1-4	C	
202		Rabbit		I			
203	Digitalin	Cat			1	C	40,80
204	Dihydroergotamine methanesulphonate	Guinea pig	0.4-1.0	C			16
205	Dihydro-β-erythroidine	Dog			2	I	114
206	Diisopropylfluorophosphate (DFP)	Dog			7-20	C	122-124
207		Guinea pig		C			
208	N, N-Dimethylhexahydronicotinic acid methyl ester iodide	Cat			0.3	C	125
209	N-Dimethyl-histamine	Guinea pig	0.2-1.0	C			126
210	Diphenhydramine (Benadryl; β-Dimethyl-	Cat			2-10	C	43,60,127
211	aminoethyl benzhydryl ether)	Dog			2	C	
212		Guinea pig	0.3-400	C			
213		Guinea pig	1000	D			
214	Emetine	Guinea pig	10,000	I			39,128
215		Ox	300	D			
216	Ergot[2]	Cat				I	77,80,129

/1/ Including introcostrin. /2/ Including ergotine and secacornine.

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect: Local µg/ml	Effect: Local Action	Effect: Systemic mg/kg	Effect: Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
217	Ergot[1] (concluded)	Dog		I		(C)	77,80,129
218		Rabbit			250	C	
219	Ergotamine (Femergin)	Cat		C	2	C	16,22,26,
220		Dog		C	2	C	68,76,97
221		Guinea pig	1-10	C			
222		Pig		C			
223		Rabbit		C			
224	Ergotoxine ethanesulphonate[2]	Cat		C	10	C	15,31,42,62,
225		Dog		C		(C)	68,76,
226		Guinea pig	1-5	C			130-132
227		Pig	80	C			
228		Rabbit		C			
229	Ether (Diethyl ether)	Guinea pig	3000	D			2,31,39,56
230		Ox		D			
231		Pig		A			
232	Ethylcholine	Dog			1	C	133
233		Guinea pig		C			
234	Ethylenediamine	Guinea pig	10-250	C			15,50,53
235		Rabbit		I			
236	N-Ethyl-histamine	Guinea pig			2	C	126
237	Ethyl-β-methylcholine	Dog			1	I	133
238		Guinea pig		C			
239	Ethylmorphine (Dionine)	Dog			3	C	29,79
240	Ethyl-urethane (Urethane, q.v.)	Ox		D			39
241	α-Eucaine	Pig		D			31
242	β-Eucaine (Benzamine; Betacaine)	Pig	80	D			31
243	(α-Furfurylethyl)trimethylammonium iodide	Guinea pig		C			89
244	Furfuryltrimethylammonium iodide (Furmethide; Furtrethonium)	Guinea pig		C			89
245	Gallamine (Flaxedil)	Man	1000	I			15
246	Gelatin	Guinea pig	10,000	I			1
247	Gelsemine	Pig		D			31
248	Gitalin	Cat		I			84
249	Glyceryl trinitrate (Nitroglycerin;	Dog				D	129
250	Trinitrin)	Rabbit			1.3	D	
251	Glycogen	Guinea pig	1000	I			1
252	Gold chloride	Cat				C	80
253	Guanidine	Guinea pig	200-1000	C			15,38
254	Guanine (2-Amino-6-oxo-purine)	Guinea pig	<40	I			15,31
255		Pig		D			
256	Guanosine (9-Guanine-ribofuranoside)	Guinea pig	20-100	D			15,31
257		Pig		I			
258	Heptyl aldehyde sodium bisulphite (Hepbisul)	Guinea pig	10,000-20,000	(C)			134
259	Heptyl isothiourea	Guinea pig				(C)	135
260	Heroine (Diacetylmorphine)	Dog			2	C	29,31
261		Pig		(C)			
262	Hexaethyltetraphosphate (HETP)	Dog			0.6-1.3	C	136
263	Hexamethonium	Guinea pig	200-800	(C)			16
264	Histamine (Ergamine; β-Imidazolylethylamine	Man	0.1-10	C	0.1	C	1,3,4,6,8,10,
265		Man	1000	(D)			12,15,17,
266		Cat	2-10	(C)	0.003-1	C	21,32,39,
267		Dog	1-1000	C	0.001-4.0	C	45,53,55,
268		Guinea pig	0.2-100	C	0.0001-1.0	C	56,62,66,
269		Guinea pig	100-10,000	(C)			68,77,79,
270		Monkey		C			84,95,102,
271		Ox	10	(C)			126,128,
272		Pig		C			137-151
273		Rabbit	<1000	(I)	40	I	
274		Rabbit			0.04-2.0	C	
275		Rat		(I)			
276		Frog	0.01-20	C	1-10	C	

/1/ Including ergotine and secacornine. /2/ Mainly ergocornine, plus a little ergocristine and ergocryptine.

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect				Reference
			Local		Systemic		
			μg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
277	Homatropine (Tropine mandelate)	Dog			0.2	D	74
278	Homatropine methylbromide (Novatropine; Tropine-N-methylbromide mandelate)	Guinea pig	10	I			43
279	Hydantoin	Guinea pig	10-100	I			15
280	Hydrastine	Guinea pig		I			112
281	Hydrastinine	Dog			1	D	66
282	Hydrochloric acid	Guinea pig		C[1]			10,31,36,39, 60,152
283		Ox		(D)			
284		Pig		C			
285		Frog		D			
286	Hydrocyanic acid	Cat				D	80
287	Hydroquinone	Dog			15	(D)	131
288	d-3-Hydroxy-N-allylmorphinan (Ro 1-7059)	Cat			1	I	119
289	l-3-Hydroxy-N-allylmorphinan (Ro 1-7700)	Cat			1	I	119
290	m-Hydroxybenxyldimethylamine methylcarbamate	Cat				(C)	27
291	p-Hydroxybenzyldimethylamine methylcarbamate	Cat				(C)	27
292	o-Hydroxybenzyldimethylamine methylcarbamate methiodide	Cat				(C)	27
293	(2-Hydroxy-5-phenylbenzyl)trimethylammonium dimethylcarbamate (Nu-683)	Dog			0.5	C	122
294	(m-Hydroxyphenyl)diethylmethylammonium bromide (Ro 2-2980)	Guinea pig	<100	I			153
295	(m-Hydroxyphenyl)dimethylethylammonium bromide (Ro 2-3198)	Guinea pig	<100	I			153
296	[α-(m-Hydroxylphenyl)-ethyl] dimethylamine methylcarbamate (Miotine)	Cat			0.4	C	27,154
297	(m-Hydroxyphenyl)trimethylammonium bromide (Ro 2-2561)	Guinea pig	<100	I			153
298	5-Hydroxytryptamine creatinine sulphate (Serotonin)	Man		D			13,91,119, 144,155-160
299		Cat		C	0.003-1.0	C	
300		Guinea pig	5	C	0.003-0.2	C	
301		Rabbit		C			
302	Hypoxanthine (6-Oxo-purine)	Guinea pig	4-40	I			15,31
303		Pig		D			
304	Kallikrein (Padutin)	Cat		D			34,85
305	Kalmia angustifolia[2] extract	Guinea pig		C			161
306	Kaolin	Guinea pig	10,000	C			36
307	Khellin	Cat			40-70	D	44,162
308		Guinea pig	2-10	D			
309	Lactic acid	Guinea pig		D			152
310	Levomethorphan (Ro 1-7788; l-3-Methoxy-N-methyl-morphinan)	Cat			1	I	119
311	Levorphan (Ro 1-5431/7; Levo-dromoran; l-3-Hydroxy-N-methyl-morphinan)	Cat			1	D	119
312	Lithium chloride	Pig		I			39
313	Lobelanidine	Cat			3	D	163
314	Lobelanine	Cat				(D)	163
315	Lobeline	Cat			1	(D)	5,16,31,80, 97,163, 164
316		Dog			3	(A)	
317		Guinea pig	10-50	C			
318		Guinea pig	80-100	D			
319		Ox	150-250	D			
320		Pig		D			
321	Magnesium chloride	Dog		D			2,10,39,97
322		Guinea pig		D			
323		Ox		D			
324		Frog	3000	(C)			
325	Magnesium sulphate	Guinea pig		D			165

/1/ pH 5 to pH 2. /2/ Lambkill.

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect				Reference
			Local		Systemic		
			µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
326	Melamine (2, 4, 6-Triaminotriazine)	Guinea pig	200-800	D			15
327	Meperidine (Demerol; Dolantal; Dolantin; Dolosal; Pethidine; Ethyl-1-methyl-4-phenylpiperidine-4-carboxylate)	Guinea pig		D			166
328	Methacholine (Amechol; Mecholyl;	Man		C	0.5	C	2,114,133,
329	Acetyl-β-methylcholine)	Cat		C			167-169
330		Dog	1	C	0.001-0.1	C	
331		Guinea pig		C			
332		Rat		C			
333	Methaphenilene (Diatrine; N-(2-Thenyl)-N-	Cat			1-5	C	60
334	phenyl-N', N'-dimethyl-ethylenediamine)	Dog			2	C	
335		Guinea pig	1-140	C			
336		Guinea pig	200-1000	D			
337	Methapyrilene (Histadyl; Thenylene; N-(2-	Cat			2.5-10	C	60
338	Thenyl)-N-(2-pyridyl)-N', N'-dimethyl-	Dog			2	C	
339	ethylenediamine)	Guinea pig	0.2-200	C			
340		Guinea pig	1000	D			
341	Methenamine (Cystogen; Cystomine; Formin;	Dog				D	15,37
342	Hexamine; Uritone; Urotropine; Hexamethylenetetramine)	Guinea pig	200-1000	I			
343	2-Methyl-4-amino-5-cyano-pyrimidine	Guinea pig	10	(D)			15
344	2-Methyl-4-amino-5-methylamino-pyrimidine (B_1-pyrimidine; Grewe diamine)	Guinea pig	100	(D)			15
345	β-Methylcholine ethyl ether	Dog				C	167
346	2-Methyl-4, 6-dihydroxy-pyrimidine	Guinea pig	<100	I			15
347	(5-Methylfurfuryl)trimethylammonium iodide (Methyl-furmethide)	Guinea pig			5-50	C	20
348	N-Methyl-histamine	Guinea pig			0.1-0.3	C	126
349	Methyl-isothiourea	Guinea pig			2-5	(I)	135
350	Morphine	Cat		C	20	C	2,31,39,40,
351		Dog		C	0.8-5.0	C	56,68,76,
352		Guinea pig	1000	I	25	(I)	79,80,
353		Ox	1000	D			170,171
354		Pig	200	(C)			
355		Rabbit		I			
356	β-Morpholinoethyl diphenylhydroxy thioacetate (Ro 3-0368)	Rabbit	20	(D)			83,121
357	γ-Morpholinopropyl diphenylhydroxy	Guinea pig		D			83,121
358	thioacetate (Ro 3-0299)	Rabbit	20-50	(D)			
359	Muscarine	Cat				C	10,70,80,82,
360		Dog		C		C	84,87,96,
361		Guinea pig	0.007-0.05	C		C	113,129,
362		Ox		C			143,172-
363		Pig		C			174
364		Rabbit	0.007	C		C	
365		Frog		C			
366		Turtle				C	
367	2-α-Naphthylethyl isothiourea	Cat			0.01-0.02	C	127
368	Narceine	Dog				I	29,31,110
369		Pig	200	D			
370	Narcotine (Gnoscopine)	Dog			3	C	29,31,110
371		Pig				D	
372	Neopine	Dog				C	29
373	Neurine (Vinyltrimethylammonium hydroxide)	Cat				C	80
374	Nicotine[1]	Man		I			2,10,16,31,
375		Cat		(C)	3	C	37,40,56,
376		Cat			10	D	62,77,80,
377		Dog	5-2000	C		A	84,130,
378		Guinea pig	20-1000	A			137,175,
379		Ox	1000	I			176

/1/ See also sodium nicotinate.

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect				Reference
			Local		Systemic		
			µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
380	Nicotine[1] (concluded)	Pig	80	A			
381		Frog	0.1-1.0	D		A	
382	Nucleic acid, thymus	Pig		I			31
383	Nucleic acid, yeast	Pig		I			31
384	Ovalbumin	Guinea pig		I			97
385	Pantopium (Omnopon; Pantopon)[2]	Dog			3	C	29,31
386		Pig	20	D			
387	Papaverine	Cat	4-20	D			2,10,11,15,
388		Dog		D	1-2	D	31,43,48,
389		Guinea pig	0.5-5	D	25-80	D	83,84,98,
390		Ox	50-100	D			109,171,
391		Pig	50	D			177-181
392		Rabbit	<100	(I)			
393		Frog	50-200	D			
394	Pavatrine (β-Dimethylaminoethyl fluorene-9-carboxylate)	Guinea pig			<50	I	171
395	Pentamidine isethionate	Guinea pig			25	C	14
396	Pentylenetetrazole (Cardiazol; Metrazol;	Guinea pig		I			10,97
397	Pentamethylene tetrazole)	Frog	0.4	C			
398	Peptone	Cat	<50	I	20-50	C	1,6,12,39,
399		Dog			0.1-0.2	C	40,56,84,
400		Guinea pig	300-10,000	C	7	C	94,96,
401		Ox		I			114,127,
402		Frog	<100	I			143,180, 182-184
403	Phenacaine (Holocaine)	Pig		D			31
404	Phenindamine (Thephorin; Nu 1504; 2-	Cat			1-10	C	60
405	Methyl-9-phenyl-2, 3, 4, 9-tetrahydro-	Dog			1	C	
406	1-pyridindene)	Guinea pig	1-400	C			
407		Guinea pig	1000	D			
408	1-Phenoxy-2-dimethylamino-ethane	Guinea pig		C			185
409	Phenoxyethyldiethylamine (928 F)	Guinea pig		I			186
410	Phentolamine (Regitine; Rogitine; C 7337; 2-[N-p'-Tolyl-N-(m'-Hydroxyphenyl)-aminomethyl] -imadazoline)	Rabbit		I			187
411	N-Phenyl-N-ethyl-N', N'-diethyl-ethylenediamine (1571F)	Guinea pig		C			188
412	(α-Phenylethyl)trimethylammonium iodide	Guinea pig		I			89
413	Physostigmine (Eserine)	Man	20-100	C			2,4,9,10,15,
414		Cat		C	0.1-2.0	C	17,31,39,
415		Dog		C	0.1-2.5	C	40,56,62-
416		Guinea pig	100	C	0.75	C	64,68,71,
417		Ox		I			76,80,84,
418		Pig		C			122,129,
419		Rabbit		C	0.3	C	171,189-
420		Frog	10-200	C			191
421	Pilocarpine	Man	0.1-1.0	C	<0.1	I	2,5,16,17,
422		Cat	0.2	C	0.1-12.0	C	19,31,37,
423		Dog	0.1-1.0	C	0.05-2.0	C	39,47,54,
424		Guinea pig	1-1000	C			56,57,62,
425		Ox	1-75	C			64,68,71,
426		Pig	30-40	C			73,76,80-
427		Rabbit	10	C	2	C	82,84,94,
428		Turtle			10	C	129,131, 149,174, 192-200
429	ψ-Piperidinoamyl diphenylhydroxythio-	Guinea pig	1-10	D			83,121
430	acetate (Ro 3-0320)	Rabbit	5-20	(D)			
431	β-Piperidinoethyl diphenylhydroxythio-	Guinea pig		D			83,121
432	acetate (Ro-0348)	Rabbit	2-10	(D)			

/1/ See also sodium nicotinate. /2/ Mixed opium alkaloids.

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect				Reference
			Local		Systemic		
			μg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
433	γ-Piperidinopropyl diphenylhydroxythioacetate (Ro 3-0290)	Guinea pig		(D)			121
434	Piperoxan (Benodaine; 933 F; Piperidinomethylbenzodioxane)	Dog			10	I	22,186
435		Guinea pig		C			
436	Potassium chloride	Man		C			3,10,31,36, 39,201
437		Cat		C			
438		Dog		C			
439		Guinea pig	1000-2500	C			
440		Ox	2000	C			
441		Pig	2500	(D)			
442		Rabbit		C			
443		Rat		C			
444		Frog		A			
445	Primary albumose	Dog			200	C	202
446	Procaine (Novocaine)	Man	100	(D)			15,31
447		Guinea pig	<10	I			
448		Guinea pig	100	(D)			
449		Pig		D			
450	Promethazine (Phenergan; 3277 RP; N-(2-Dimethylamino-2-methylethyl)-phenothiazine)	Man	400	(D)			60
451		Cat			1-5	C	
452		Dog			1	C	
453		Guinea pig	0.3-200	C			
454		Guinea pig	1000	D			
455	Prosympal (883 F; Diethylaminomethylbenzodioxane)	Guinea pig		C			186
456	Protoveratrine	Ox	70	I			39
457	Putrescine	Guinea pig		C			38
458	β-(3-Pyrazole)-ethylamine	Guinea pig	40-200	C			203
459	β-(2-Pyridyl)-ethylamine	Guinea pig	1-40	C			203,204
460	Pyrilamine (Mepyramine; Neoantergan; Pyranisamine; N-(p-Methoxybenzyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylenediamine)	Man	4-200	C			17,25,60
461		Cat			1-10	C	
462		Dog			1	C	
463		Guinea pig	0.4-700	C			
464		Guinea pig	1000	D			
465	Quebrachamine	Cat				I	72
466		Ox		I			
467	Quebrachine	Cat				I	72
468		Ox		I			
469	Quinine	Dog				C	10,31,37,39, 56
470		Guinea pig	1000	(D)			
471		Ox		D			
472		Pig		D			
473		Frog	200	C			
474	Quinine methochloride	Dog			10	C	114
475	Semicarbazide	Guinea pig	<100	I			204
476	Sodium azide	Guinea pig		D			205,206
477	Sodium bromide	Ox		I			31,39
478		Pig	2000-4000	D			
479	Sodium camphorate	Dog				I	37
480	Sodium cyanate	Guinea pig	10-400	D			15,207
481	Sodium cyanide	Cat		C			2
482	Sodium hydroxide	Guinea pig		C[1]			10,31,36,39, 60
483		Ox		(C)			
484		Pig		A			
485		Frog		(C)			
486	Sodium iodide	Dog	250,000	D		I	31,37,39, 56,77
487		Guinea pig	15,000	D			
488		Ox	4000	C			
489		Pig	2500	D			
490	Sodium nicotinate	Dog		(I)			45

/1/ At pH 11.

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect				Reference
			Local		System		
			µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
491	Sodium nitrate	Ox		I			31,39
492		Pig	3000	(C)			
493	Sodium nitrite	Guinea pig	8000	I	80	D	10,31,39, 56,214
494		Ox	2000	C			
495		Pig	1000	D			
496		Frog	140	D			
497	Sodium nucleinate	Guinea pig		C			38
498	Sodium theophyllinate	Rabbit	500	I			53
499	Sodium thiocyanate	Guinea pig	10,000	I			39,56,94
500		Ox		C			
501	Sodium m-vanadate	Dog			2	C	208
502	Sodium o-vanadate	Dog			2	C	37,56
503		Guinea pig	2000	C			
504	Sparteine	Guinea pig	100	C			16
505	Staphylococcus toxin	Guinea pig		C			209
506	Starch (Amylum)	Guinea pig	10,000	I			1
507	Stovaine	Pig	200	D			31
508	Strontium chloride	Ox		C			39
509	Strophanthin	Cat		I			84
510	Strychnine	Cat		I			39,56,77,84
511		Dog		(D)			
512		Guinea pig		I			
513		Ox	1000	D			
514	Substance P	Man		I			91
515		Cat		I			
516	Suramin	Cat			250	(D)	14
517	Syntropan (Amprotropine; 3-Diethylamino-2, 2-dimethyl-propyl tropate)	Guinea pig	10	I			43
518	Tetramethylammonium chloride	Guinea pig	80	C			16
519	Tetraethylpyrophosphate (TEPP)	Guinea pig		C			123
520	Tetrahydropapaveroline	Cat			2-10	D	196
521	Tetramethylene diisothiourea	Guinea pig			5	(D)	135
522	Thebaine)	Dog			1	C	31,66,110
523		Pig				(C)	
524	Theobromine (3, 7-Dimethylxanthine)	Cat				D	15,31,95
525		Dog				D	
526		Guinea pig	40-100	D		D	
527		Pig	70	D			
528	Theophylline (1, 3-Dimethylxanthine)	Cat				D	15,53,95, 210
529		Dog				D	
530		Guinea pig	10-100	D		D	
531		Rabbit	200	I			
532	Theophylline monoethanolamine (Theamin)	Cat				D	95
533		Dog				D	
534		Guinea pig			10-15	D	
535	Theophylline sodium acetate (Theocin)	Dog			10-60	D	50
536		Guinea pig		D			
537	Thymine (5-Methyluracil)	Guinea pig	10-100	I			15
538	Thymoxyethyldiethylamine (929 F)	Guinea pig		C	5	C	186,188
539	Thyroid extract	Cat				(D)	62
540		Rabbit				(D)	
541	Thyroxine	Frog	0.001-0.01	C			6
542	d-Tubocurarine	Man	400	D			15,114
543		Dog			0.3	A	
544	Trasentine (Adiphenine; Diethylaminoethyl diphenylacetate)	Guinea pig	10	I			43,99
545	Tribromoethanol	Dog				I	92
546	Trichloroethanol	Dog				I	92
547	Trimethylamine	Dog				D	37
548	Trimethyl(2-aminoethyl)ammonium chloride	Rabbit		C			107
549	Trimethyl(2-chloroethyl)ammonium chloride	Rabbit		C			107

133. DIRECT ACTION OF DRUGS ON THE BRONCHI (Continued)

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect: Local µg/ml	Effect: Local Action	Effect: Systemic mg/kg	Effect: Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
550	Trimethyl(2-methylaminoethyl)ammonium chloride	Rabbit		C			107
551	Tripelennamine (Pyribenzamine; N-(2-Pyridyl)-N-benzyl-N', N'-dimethylethylenediamine)	Cat			0.2-10	C	60
552		Dog			1	C	
553		Guinea pig	0.4-300	C			
554		Guinea pig	1000	D			
555	Typhobacterin	Guinea pig				C	35
556	Uracil (2, 4-Dioxopyrimidine)	Guinea pig	<10	I			15
557	Urea	Guinea pig	<1000	I			15
558	Urethane (Ethyl urethane, q.v.)	Cat		D		D	31,56,80,81, 84,190
559		Guinea pig	10,000	D			
560		Pig		D			
561		Rabbit	5,000-10,000	D			
562		Sheep	5,000-10,000	D			
563	Uric acid	Guinea pig	200-400	I			15
564	Venom of Crotalus atrox	Cat		C			211
565		Guinea pig		C			
566	Venom of Denisonia superba	Cat		(C)			211
567		Guinea pig		(C)			
568	Venom of Naia naia	Cat		C			211
569		Guinea pig		C			
570	Veratrine	Cat	10-30	C	0.3	C	10,39,77,80, 127
571		Dog	3	D			
572		Ox	<300	I			
573		Frog	1-10	D			
574	Visammin	Dog				D	212
575		Pig		D			
576	Xanthine (2, 6-Dioxopurine)	Cat				D	15,31,95
577		Dog				D	
578		Guinea pig	<10	I		D	
579		Pig	0.5-1	D			
580	Xysmalobinum	Cat			0.25	C	213
581	Zinc sulphate	Frog	600-3000	C			10

Contributor: Hawkins, D. F.

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Drugs are listed to illustrate, as far as possible, the relationship between chemical structure and pharmacological action. Inclusion of trade names is for informative purposes only and in no way implies endorsement by The National Academy of Sciences-The National Research Council. For all "effects" included in this table, there is reasonable evidence the drug in fact acted on the bronchial musculature. Where there was evidence that an effect was mediated by the respiratory center or adrenal glands, it was excluded. Drug actions influencing only anaphylactic or asthmatic bronchospasm, or other pathological states of the bronchi, were also excluded. Concentrations of drugs are given in mμg/ml for local actions on isolated preparations, and doses in μg/kg for drugs administered systemically. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted. A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive.

	Compound (Synonym)	Species	Effect: Local mμg/ml	Effect: Local Action	Effect: Systemic μg/kg	Effect: Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	1-Phenyl-2-amino Alkanes and Alkanols						
1	1-Phenyl-2-amino-ethane (β-Phenylethylamine)	Cat			2000	D	1-4
2		Dog			2000	D	
3		Guinea pig		I	2,000-20,000	(C)	
4		Rabbit				I	
5	1-Phenyl-2-amino-ethanol (Phenylethanolamine)	Cat				(I)	3,5,6
6		Dog				(I)	
7		Guinea pig		D	10,000	D	
8		Rabbit			2000-4000	D	
9	1-Phenyl-2-isopropylamino-ethanol (WIN 5528; 859)	Guinea pig		D			5,8,9
10	1-Phenyl-2-amino-propane (Amphetamine; Benzedrine)	Cat			1000-2000	D	2,7,10-15
11		Dog	400,000	C	2,000-10,000	(D)	
12		Guinea pig		C		C	
13		Guinea pig	250,000	D	10,000	(D)	
14	d-1-Phenyl-2-methylamino-propane (Methamphetamine; Methedrine)	Cat				(D)	11,16
15		Guinea pig	1000-5000	D			
16		Guinea pig	100,000	(C)			
17	1-Phenyl-2-dimethylamino-propane	Cat			1000	D	11
18	1-Phenyl-2-benzylamino-propane	Cat			1000	D	11
19	1-Phenyl-2-amino-propanol (Mydriatin; Norephedrine; Propadrine)	Dog			5000	I	3,10,14
20		Guinea pig		C			
21		Rabbit			4500	D	
22	1-Phenyl-2-methylamino-propanol (dl-Ephedrine, Ephetonin, Racephedrine)	Dog			2000	D	17,26
23		Frog	400,000				
24	l-1-Phenyl-2-methylamino-propanol (Ephedrine)	Man	5,000-100,000	D	500-600	D	3,7,10 14-16, 18-41, 43,44, 46-49, 51
25		Cat	1,000-100,000	D	1000-1500	D	
26		Dog	10,000	D	1,000-10,000	D	
27		Guinea pig	1,000-10,000	D	5,000-70,000	(I)	
28		Guinea pig	400,000-1,000,000	(C)			
29		Rabbit	100,000-1,000,000	A	4000-6000	D	
30		Rat	10,000	D			
31		Frog	400,000	D			
32	ψ-1-Phenyl-2-methylamino-propanol (Pseudo-ephedrine)	Cat		D			16,39,40, 46,47
33		Dog		D	2000	D	
34		Guinea pig	2,000-100,000	D			
35		Guinea pig	500,000	(C)			
36		Rabbit	10,000	D			
37		Rabbit	100,000-500,000	C			
38	d-ψ-1-Phenyl-2-methylamino-propanol (d-Pseudo-ephedrine)	Guinea pig			20,000	D	7
39	l-1-Phenyl-2-dimethylamino-propanol (N-Methyl-ephedrine)	Cat				D	18
40	l-1-Phenyl-2-(ethyl-methylamino)-propanol (N-Ethyl-ephedrine)	Cat		D		D	18,20
41		Dog			5000	D	
42		Guinea pig		D			
43		Rabbit		D			

134. SYMPATHOMIMETIC AMINES AND RELATED DRUGS ACTING ON THE BRONCHI (Continued)
A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect: Local mμg/ml	Effect: Local Action	Effect: Systemic μg/kg	Effect: Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	1-Phenyl-2-amino Alkanes and Alkanols (concluded)						
44	l-1-Phenyl-2-[(β-hydroxyethyl)-methyl-amino]-propanol (N-Ethanol-ephedrine)	Cat				I	18
45	1-Phenyl-2-(diethylaminoethyl-methyl-amino)-propanol (Isalon)	Cat			5,000-10,000	D	19,50,51
46		Dog			10,000	D	
47		Guinea pig		D			
48		Rabbit		D			
49	1-Phenyl-2-(dibutylaminoethyl-methyl-amino)-propanol	Rabbit		D			19
50	l-1-Phenyl-2-(propyl-methylamino)-propanol (N-Propyl-ephedrine)	Cat				I	18
51	l-1-Phenyl-2-(isopropyl-methylamino)-propanol (N-Isopropyl-ephedrine)	Cat				I	18
52	1-Phenyl-2-[(β-hydroxypropyl)-methyl-amino]-propanol (S 166)	Guinea pig		I			52
53	1-Phenyl-2-[(β-hydroxypropyl)-methyl-amino]-propanol methiodide (S 164)	Guinea pig		I			52
54	l-1-Phenyl-2-(butyl-methylamino)-propanol (N-Butyl-ephedrine)	Cat				I	18
55	1-Phenyl-2-diethylamino-propanol (N,N-Diethyl-norephedrine)	Cat			5,000	D	18
56	1-Phenyl-2-amino-butane	Guinea pig		I			1
57	2-Phenyl-3-methylamino-butanol	Guinea pig			30,000	I	7
	1-(m-Hydroxyphenyl)-2-amino Alkanols						
58	1-(m-Hydroxyphenyl)-2-amino-ethanol (WIN 5501)	Guinea pig		D			5
59	1-(m-Hydroxyphenyl)-2-methylamino-ethanol (Adrianol; Neosynephrine; Phenylephrine; m-Sympatol)	Cat			150-1000	D	5,53,54, 56
60		Dog			30	I	
61		Guinea pig		D		D	
62	1-(m-Hydroxyphenyl)-2-propylamino-ethanol (N-Propyl-noradrianol)	Dog				I	54
63	1-(m-Hydroxyphenyl)-2-isopropylamino-ethanol (WIN 5507; 539)	Guinea pig		D		D	5,9
64	1-(m-Hydroxyphenyl)-2-amino-propanol (m-Oxynorephedrine)	Dog			500-5000	I	10,14,41
65		Guinea pig		D			
66	l-1-(m-Hydroxyphenyl)-2-methylamino-propanol (m-Oxyephedrine)	Dog			1000-5000	(D)	10,14,41
67		Guinea pig		(D)			
68	1-(m-Hydroxyphenyl)-2-isopropylamino-propanol	Dog			200	I	57
69	1-(m-Hydroxyphenyl)-2-benzylamino-propanol	Dog			5000	C	57
70	1-(m-Hydroxyphenyl)-(α-phenylethylamino)-propanol	Dog			10,000	I	57
71	1-(m-Hydroxyphenyl)-2-(α-methyl-γ-phenyl-propylamino)-propanol	Dog			65	D	57
	1-(p-Hydroxyphenyl)-2-amino Alkanes and Alkanols						
72	1-(p-Hydroxyphenyl)-2-amino-ethane (Tyramine)	Cat		(A)	100-20,000	(D)	2,3,16, 58-67
73		Dog	100,000	C	2,000-20,000	(D)	
74		Guinea pig	4000-8000	D	40,000	D	
75		Guinea pig	1,000,000	C	100,000	(C)	
76		Monkey		(D)			
77		Ox	100,000	C			
78		Rabbit			2500	(D)	
79	1-(p-Hydroxyphenyl)-2-dimethylamino-ethane (Hordenine)	Dog			4000	D	42,64
80		Rabbit			2,000-15,000	D	

134. SYMPATHOMIMETIC AMINES AND RELATED DRUGS ACTING ON THE BRONCHI (Continued)

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect: Local mμg/ml	Effect: Local Action	Effect: Systemic μg/kg	Effect: Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	1-(p-Hydroxyphenyl)-2-amino Alkanes and Alkanols (continued)						
81	1-(p-Hydroxyphenyl)-2-amino-ethanol	Cat				D	5,8,68
82	(Norsympatol; WIN 5512; 582)	Guinea pig		(D)			
83	1-(p-Hydroxyphenyl)-2-methylamino-ethanol (Synephrine; Sympatol)	Cat			1,500-30,000	D	5,8,34,48,54,69,70
84		Dog			500	(D)	
85		Guinea pig		D	12,000	D	
86		Rabbit			30,000	D	
87	l-1-(p-Hydroxyphenyl)-2-methylamino-	Cat			750	D	48,55
88	ethanol (l-Synephrine)	Dog				(I)	
89	1-(p-Hydroxyphenyl)-2-ethylamino-ethanol (573)	Guinea pig		D			8
90	1-(p-Hydroxyphenyl)-2-diethylamino-ethanol	Cat				D	68
91	1-(p-Hydroxyphenyl)-2-propylamino-ethanol (579)	Guinea pig		D			8
92	1-(p-Hydroxyphenyl)-2-isopropylamino-	Dog			30-500	D	5,8,9,54
93	ethanol (Isopropyl-norsympatol; WIN 833)	Guinea pig		D		D	
94	1-(p-Hydroxyphenyl)-2-butylamino-ethanol (570)	Guinea pig		D			8
95	1-(p-Hydroxyphenyl)-2-isobutylamino-ethanol (643)	Guinea pig		D			8
96	1-(p-Hydroxyphenyl)-2-sec.-butylamino-ethanol (661)	Guinea pig		D			8
97	1-(p-Hydroxyphenyl)-2-tert.-butylamino-ethanol (651)	Guinea pig		(D)			8
98	1-(p-Hydroxyphenyl)-2-amino-propane	Cat			2,000-20,000	D	2
99		Dog			2,000-20,000	D	
100		Guinea pig		I			
101	1-(p-Hydroxyphenyl)-2-methylamino-	Dog				I	7,57
102	propane (Veritol; Paredrinol; Pholedrine)	Guinea pig			20,000	(D)	
103	1-(p-Hydroxyphenyl)-2-(α,α-dimethyl-β-phenylethylamino-propane	Dog				I	57
104	1-(p-Hydroxyphenyl)-2-phenylpropylamino-propane	Dog				C	57
105	1-(p-Hydroxyphenyl)-2-(α-methyl-γ-phenylpropylamino)-propane	Dog				C	57
106	1-(p-Hydroxyphenyl)-2-methylamino-	Dog			5000	I	7,10,57,69
107	propanol (Supifene; Suprifen; p-Oxyephedrine)	Guinea pig			3,000-10,000	D	
108	1-(p-Hydroxyphenyl)-2-isopropylamino-propanol	Dog			200	C	57
109	1-(p-Hydroxyphenyl)-2-benzylamino-propanol	Dog			5,000	C	57
110	1-(p-Hydroxyphenyl)-2-(α-phenyl-ethyl-amino)-propanol	Dog			10,000	I	57
111	1-(p-Hydroxyphenyl)-2-(β-phenylethylamino)-propanol	Dog			400	D	57
112	1-(p-Hydroxyphenyl)-2-(α-methyl-β-phenyl-ethylamino)-propanol	Dog			200	D	57
113	1-(p-Hydroxyphenyl)-2-(γ-phenylpropyl-amino)-propanol	Dog			160	D	57
114	1-(p-Hydroxyphenyl)-2-(α-methyl-γ-phenylpropylamino)-propanol	Dog			100	D	57
115	1-(p-Hydroxyphenyl)-2-[α-methyl-γ-(p-methoxyphenyl)-propylamino]-propanol	Dog			1000	D	57
116	1-(p-Hydroxyphenyl)-2-(α-methyl-δ-phenylbutylamino)-propanol	Dog			1000	D	57

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect: Local mμg/ml	Effect: Local Action	Effect: Systemic μg/kg	Effect: Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	1-(p-Hydroxyphenyl)-2-amino Alkanes and Alkanols (concluded)						
117	1-(p-Hydroxyphenyl)-2-methylamino-butane	Dog				I	57
118	1-(p-Hydroxyphenyl)-2-(γ-phenylpropyl-amino)-butanol	Dog			300	D	57
119	1-(p-Hydroxyphenyl)-2-(α-methyl-γ-phenyl-propylamino)-butanol	Dog			100	D	57
120	1-(p-Hydroxyphenyl)-2-(δ-phenylbutylamino)-butanol	Dog			1000	D	57
	1-(3,4-Dihydroxyphenyl)-2-amino Alkanes and Alkanols						
121	1-(3,4-Dihydroxyphenyl)-2-amino-ethane	Cat				D	2
122		Dog				D	
123		Guinea pig		D			
124	3,4-Dihydroxyphenyl-alanine	Rabbit			20,000	I	3
125	1-(3,4-Dihydroxyphenyl)-2-methylamino-	Cat			100-500	(D)	10,14,41,
126	ethane (Epinine)	Dog			400-1000	D	61-64,
127		Guinea pig		D			71,72
128		Rabbit			100-500	(D)	
129	1-(3,4-Dihydroxyphenyl)-2-isopropylamino-ethane (0-4;1554)	Guinea pig		D	100	D	71-73
130	1-(3,4-Dihydroxyphenyl)-2-amino-ethanol	Man	1000	D			10,16,32,
131	(Arterenol; Noradrenaline)	Cat			50-250	D	41,71,
132		Dog			40-200	D	73-76
133		Guinea pig	100-1000	D	30-250	D	
134	d-1-(3,4-Dihydroxyphenyl)-2-amino-ethanol (d-Arterenol)	Guinea pig		D	1000	D	77
135	1-1-(3,4-Dihydroxyphenyl)-2-amino-ethanol	Man	1000	D			9,16,38,
136	(1-Arterenol; Levarterenol)	Cat	10-100	D			77-79
137		Dog	40	D		(I)	
138		Guinea pig	50-500	D	50-100	D	
139		Rabbit	1000	D			
140		Rat	100	D			
141	1-(3,4-Dihydroxyphenyl)-2-methylamino-ethanol(dl-Epinephrine; Vaponephrin)	Guinea pig	100-120	D			71,75
142	1-1-(3,4-Dihydroxyphenyl)-2-methylamino-	Man	10-100	D	10	D	3,13,16,
143	ethanol (Epinephrine; Adrenalin; Supra-	Cat	1-100	D	2-2500	D	21,25,26,
144	renin)	Dog	5-100,000	D	0.5-300	D	30,32,36,
145		Guinea pig	1-100,000	D	0.5-500	D	38,43,47,
146		Monkey		D			54,55,58,
147		Ox	300-4000	D			60,62-64,
148		Pig	1,600-10,000	D			73,74,77,
149		Rabbit	1000-2000	(D)	2-100	(D)	81-112
150		Rat	10-100	D			
151		Sheep	2000	D			
152		Frog	200-10,000	D	1000	D	
153	1-(3,4-Dihydroxyphenyl)-2-dimethylamino-	Dog			400	D	113
154	ethanol (Methadren; N-Methyl-adrenaline)	Guinea pig		D			
155	1-(3,4-Dihydroxyphenyl)-2-ethylamino-	Dog			0.5-3	D	9,54,71,
156	ethanol (N-Ethyl-arterenol; WIN 5564; 1516)	Guinea pig	30-50	D	100	D	73,75
157	1-(3,4-Dihydroxyphenyl)-2-(β-hydroxy-ethylamino)-ethanol (JB 254)	Dog			7	D	45
158	1-(3,4-Dihydroxyphenyl)-2-propylamino-	Dog			0.5-7	D	9,54,75,
159	ethanol (N-Propyl-arterenol; WIN 5587)	Guinea pig	300-500	D	100	D	114
160	1-(3,4-Dihydroxyphenyl)-2-isopropylamino-	Man	10	D	2	D	7,16,21,31,
161	ethanol (Isoprenaline; Isoproterenol;	Cat	10	D			32,38,54,
162	Alcudrin; Isuprel; Neo-epinine)	Dog	5-10,000	D	0.5-1	D	57,73,75,
163		Guinea pig	0.5-30	D	10-1000	D	114-116
164		Rabbit	100	D			
165		Rat	10	D			
166	1-(3,4-Dihydroxyphenyl)-2-(β-hydroxy-propylamino)-ethanol (JB 253)	Dog			8	D	45

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect				Reference
			Local		Systemic		
			mμg/ml	Action	μg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	1-(3,4-Dihydroxyphenyl)-2-amino Alkanes and Alkanols (continued)						
167	1-(3,4-Dihydroxyphenyl)-2-butylamino-ethanol (N-Butylarterenol; WIN 5590; SKF 690A; 1960)	Dog			5	D	9,16,54, 71,114
168		Guinea pig	4-10	D	25	D	
169	1-(3,4-Dihydroxyphenyl)-2-isobutylamino ethanol (WIN 5595)	Dog			50	D	9,54,114
170		Guinea pig		D	250	D	
171	1-(3,4-Dihydroxyphenyl)-2-sec.-butylamino-ethanol (WIN 5559; 0-4;1424)	Guinea pig	30-50	D	25-100	D	9,71,73,75, 115
172	1-(3,4-Dihydroxyphenyl)-2-(α-methyl-propylamino)-ethanol	Dog			0.7	D	57
173	1-(3,4-Dihydroxyphenyl)-2-tert.-butylamino-ethanol (WIN 5563; 1505)	Dog			0.4	D	9,57,71,75
174		Guinea pig	8-12	D			
175	1-(3,4-Dihydroxyphenyl)-2-amylamino-ethanol (WIN 5596)	Guinea pig		D	100	D	9,114
176	1-(3,4-Dihydroxyphenyl)-2-(α-ethylpropyl-amino)-ethanol (WIN 5592)	Guinea pig		D	500	D	9,114
177	1-(3,4-Dihydroxyphenyl)-2-(α,β-dimethyl-propylamino)-ethanol (WIN 5593)	Guinea pig		D	100	D	9,114
178	1-(3,4-Dihydroxyphenyl)-2-(α-methyl-amylamino)-ethanol (JB 226)	Dog			7	D	45
179	1-(3,4-Dihydroxyphenyl)-2-cyclopentyl-amino-ethanol (WIN 5591)	Guinea pig		D	100	D	9,114
180	1-(3,4-Dihydroxyphenyl)-2-cyclohexylamino-ethanol (WIN 5589)	Guinea pig		D	100	D	9,114
181	1-(3,4-Dihydroxyphenyl)-2-β-phenyl-ethylamino-ethanol	Dog			6	D	57
182	1-(3,4-Dihydroxyphenyl)-2-(α-methyl-β-phenylethylamino)-ethanol (JB 230)	Dog			4	D	45
183	1-(3,4-Dihydroxyphenyl-2-[α-methyl-β-(p-methoxyphenyl)ethylamino]-ethanol (JB 245)	Dog			1.5	D	45
184	1-(3,4-Dihydroxyphenyl)-2-[α-methyl-β-(3',4'-methylenedioxyphenyl)ethylamino]-ethanol (JB 251)	Dog			2	D	45
185	1-(3,4-Dihydroxyphenyl)-2-γ-phenyl-propylamino-ethanol (JB 246)	Dog			2	D	45,57
186	1-(3,4-Dihydroxyphenyl)-2-amino-propane	Cat				D	2
187		Dog				D	
188		Guinea pig		D			
189	1-(3,4-Dihydroxyphenyl)-2-isopropylamino-propane (SKF 364)	Guinea pig	100-200	D			16
190	1-(3,4-Dihydroxyphenyl)-2-amino-propanol (Cobefrine; Corbasil; Dioxynorephedrine)	Dog			1000-3000	D	7,9,10,14
191		Guinea pig		D	500	D	
192	1-(3,4-Dihydroxyphenyl)-2-methylamino-propanol (Dioxyephedrine)	Dog			400	D	7,9,10,14
193		Guinea pig		D	100	D	
194	1-(3,4-Dihydroxyphenyl)-2-isopropylamino-propanol (WIN 5570)	Guinea pig		I			9
195	1-(3,4-Dihydroxyphenyl-2-cyclopentyl-amino-propanol (WIN 3357)	Guinea pig		I			9
196	1-(3,4-Dihydroxyphenyl)-2-cyclohexylamino-propanol (WIN 514)	Guinea pig		D			9
197	1-(3,4-Dihydroxyphenyl)-2-phenyl-propylamino-propanol	Dog			3	D	57
198	1-(3,4-Dihydroxyphenyl)-2-(a-methyl-γ-phenylpropylamino)-propanol	Dog			10	(D)	57
199	1-(3,4-Dihydroxyphenyl)-2-amino-butanol (Ethyl-norsuprarenin; Butanefrine)	Dog			1000	(D)	9,10,14,41,78
200		Guinea pig		D		D	
201	1-(3,4-Dihydroxyphenyl)-2-isopropylamino-butanol (WIN 3046)	Dog				D	9,78
202		Guinea pig		D		D	
203	1-(3,4-Dihydroxyphenyl)-2-cyclopentyl-amino-butanol (WIN 515)	Dog				D	9,78
204		Guinea pig		D		D	

134. SYMPATHOMIMETIC AMINES AND RELATED DRUGS ACTING ON THE BRONCHI (Continued)

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect: Local mμg/ml	Effect: Local Action	Effect: Systemic μg/kg	Effect: Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	1-(3,4-Dihydroxyphenyl)-2-amino Alkanes and Alkanols (concluded)						
205	1-(3,4-Dihydroxyphenyl)-2-cyclohexylamino-butanol (WIN 713)	Guinea pig		D		D	9,78
206	1-(3,4-(Dihydroxyphenyl)-2-(α-methyl-γ-phenyl-propylamino)-butanol	Dog			40	D	57
207	1-(3,4-Dihydroxyphenyl)-2-amino-pentanol (WIN 3356)	Guinea pig		I			9
208	1-(3,4-Dihydroxyphenyl)-2-isopropylamino-pentanol (WIN -3243)	Guinea pig		I			9
209	1-(3,4-Dihydroxyphenyl)-2-cyclopentyl-amino-pentanol (WIN 3242)	Guinea pig		(D)			9
210	1-(3,4-Dihydroxyphenyl)-2-cyclohexylamino-pentanol (WIN 3269)	Guinea pig		I			9
211	1-(3,4-Dihydroxyphenyl)-2-isopropylamino-isopentanol (WIN 3204)	Guinea pig		(D)			9
212	1-(3,4-Dihydroxyphenyl)-2-cyclopentyl-amino-isopentanol (WIN 3434)	Guinea pig		I			9
	Other Ring-substituted 1-phenyl-2-amino Alkanes and Alkanols						
213	1-(o-Methylphenyl)-2-amino-propane	Guinea pig	250,000	D			12
214	1-(m-Methylphenyl)-2-amino-propane	Guinea pig	250,000	D			12
215	1-(m-Methylphenyl)-2-amino-propanol	Dog			500-1000	I	14,41
216		Guinea pig		C			
217	1-(p-Methylphenyl)-2-amino-propane	Guinea pig	250,000	D			12
218	1-(2,5-Dimethylphenyl)-2-amino-propane	Guinea pig	250,000	D			12
219	1-(3,4-Dimethylphenyl)-2-amino-propane	Guinea pig	250,000	D			12
220	1-(m-Methoxyphenyl)-2-amino-ethane	Cat		D			27
221		Rabbit		I			
222	1-(p-Methoxyphenyl)-2-amino-ethane	Cat		D			27
223		Rabbit		I			
224	1-(3,4-Dimethoxyphenyl)-2-amino-ethane	Cat		I			27
225		Rabbit		I			
226	1-(3,4-Methylenedioxyphenyl)-2-amino-ethane	Cat	100,000	D			27
227		Rabbit		I			
228	1-(o-Methoxyphenyl)-2-amino-propane	Rabbit		I			29
229	1-(o-Methoxyphenyl)-2-methylamino-propane (Orthoxine)	Man			5000	D	21,23,29, 117
230		Guinea pig			60,000	D	
231	1-(o-Methoxyphenyl)-2-dimethylamino-propane	Rabbit		D			29
232	1-(o-Methoxyphenyl)-2-benzylamino-propane	Rabbit		D			29
233	1-(m-Methoxyphenyl)-2-amino-propane	Rabbit		D			29
234	1-(m-Methoxyphenyl)-2-methylamino-propane	Rabbit		D			29
235	1-(m-Methoxyphenyl)-2-ethylamino-propane	Rabbit		D			29
236	1-(m-Methoxyphenyl)-2-dimethylamino-propane	Rabbit		D			29
237	1-(m-Methoxyphenyl)-2-benzylamino-propane	Rabbit		D			29
238	1-(p-Methoxyphenyl)-2-amino-propane	Rabbit		D			29
239	1-(p-Methoxyphenyl)-2-methylamino-propane	Rabbit		(D)			29
240	1-(p-Methoxyphenyl)-2-ethylamino-propane	Rabbit		I			29
241	1-(p-Methoxyphenyl)-2-dimethylamino-propane	Rabbit		D			29
242	1-(p-Methoxyphenyl)-2-benzylamino-propane	Rabbit		D			29
243	1-(o-Methoxyphenyl)-2-amino-propanol	Dog			1000	I	14,41
244		Guinea pig		C			

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect: Local: mμg/ml	Effect: Local: Action	Effect: Systemic: μg/kg	Effect: Systemic: Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Other Ring-substituted 1-phenyl-2-amino Alkanes and Alkanols (concluded)						
245	1-(o-Hydroxyphenyl)-2-(α-methyl-γ-phenyl-propylamino)-propanol	Dog			2500	D	57
246	1-(3,4-Dihydroxy-6-methyl-phenyl)-2-methylamino-ethanol (6-Methyl-adrenaline)	Guinea pig				D	119
247	1-(3-Methyl-4-hydroxy-phenyl)-2-amino-propanol	Dog			1000	I	14,41
248		Guinea pig		D			
249	1-(3-Hydroxy-4-methoxy-2-allyl-phenyl)-2-amino-propane	Cat			2000	D	118
250	1-(m-Aminophenyl)-2-isopropylamino-ethanol (WIN 5503)	Guinea pig		C			9
251	1-(p-Aminophenyl)-2-methylamino-propanol (Ephetonal; p-Amino-ephedrine)	Dog			1000-5000	(I)	10,14,41
252		Guinea pig		D			
253	1-(m-Fluorophenyl)-2-isopropylamino-ethanol (WIN 5505)	Guinea pig		I			9
	2-Phenyl-1-amino Propanes						
254	2-Phenyl-1-amino-propane	Guinea pig		(C)			120
255	2-Phenyl-1-methylamino-propane	Dog			1000-5000	D	15
256	2-(o-Hydroxyphenyl)-1-amino-propane	Guinea pig		D			120
257	2-(m-Hydroxyphenyl)-1-amino-propane	Guinea pig		I			120
258	2-(p-Hydroxyphenyl)-1-amino-propane	Guinea pig		(C)			120
259	2-(2,3-Dihydroxyphenyl)-1-amino-propane	Guinea pig		I			120
260	2-(2,4-Dihydroxyphenyl)-1-amino-propane	Guinea pig		I			120
261	2-(2,5-Dihydroxyphenyl)-1-amino-propane	Guinea pig		I			120
262	2-(2,6-Dihydroxyphenyl)-1-amino-propane	Guinea pig		D			120
263	2-(3,4-Dihydroxyphenyl)-1-amino-propane	Guinea pig		(C)			120
264	2-(3,5-Dihydroxyphenyl)-1-amino-propane	Guinea pig		I			120
265	2-(o-Methoxyphenyl)-1-amino-propane	Guinea pig		I			120
266	2-(m-Methoxyphenyl)-1-amino-propane	Guinea pig		D			120
267	2-(p-Methoxyphenyl)-1-amino-propane	Guinea pig		D			120
268	2-(2,3-Dimethoxyphenyl)-1-amino-propane	Guinea pig		I			120
269	2-(2,4-Dimethoxyphenyl)-1-amino-propane	Guinea pig		D			120
270	2-(2,5-Dimethoxyphenyl)-1-amino-propane	Guinea pig		D			120
271	2-(2,6-Dimethoxyphenyl)-1-amino-propane	Guinea pig		D			120
272	2-(3,4-Dimethoxyphenyl)-1-amino-propane	Guinea pig		I			120
273	2-(3,5-Dimethoxyphenyl)-1-amino-propane	Guinea pig		D			120
	Ketones						
274	1-(o-Hydroxyphenyl)-1-oxo-2-(α-methyl-γ-phenyl-propylamino)-propane	Dog			40,000	I	57
275	1-(m-Hydroxyphenyl)-1-oxo-2-isopropylamino-propane	Dog			1000	D	57
276	1-(m-Hydroxyphenyl)-1-oxo-2-benzylamino-propane	Dog			5000	I	57
277	1-(m-Hydroxyphenyl)-1-oxo-2-(α-methyl-γ-phenyl-propylamino)-propane	Dog			2000	D	57
278	1-(p-Hydroxyphenyl)-1-oxo-2-isopropylamino-propane	Dog			2000	C	57
279	1-(p-Hydroxyphenyl)-1-oxo-2-(α-phenyl-ethylamino)-propane	Dog			40,000	I	57
280	1-(p-Hydroxyphenyl)-1-oxo-2-(α-methyl-γ-phenyl-propylamino)-propane	Dog			2000	I	57
281	1-(p-Hydroxyphenyl)-1-oxo-2-(α-methyl-γ-phenyl-propylamino)-butane	Dog			2000	D	57
282	1-(p-Hydroxyphenyl)-1-oxo-2-phenylbutyl-amino-butane	Dog			50,000	I	57
283	1-(3,4-Dihydroxyphenyl)-1-oxo-2-methylamino-ethane (Adrenalone; Kephrine; Stryphnon)	Guinea pig		D	10,000	(I)	3,7,71,72
284		Rabbit			500	D	
285	1-(3,4-Dihydroxyphenyl)-1-oxo-2-isopropylamino-ethane (1590)	Guinea pig		D			71
286	1-(3,4-Dihydroxyphenyl)-1-oxo-2-(α-methyl-γ-phenylpropylamino)-ethane	Dog			140	(D)	57

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	Compound (Synonym)	Species	Effect: Local, mμg/ml	Effect: Local, Action	Effect: Systemic, μg/kg	Effect: Systemic, Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Ketones (concluded)						
287	1-(3,4-Dihydroxyphenyl)-1-oxo-2-isopropylamino-propane	Dog			65	D	57
288	1-(3,4-Dihydroxyphenyl)-1-oxo-2-benzylamino-propane	Dog			3500	D	57
289	1-(3,4-Dihydroxyphenyl)-1-oxo-2-(α-phenylethylamino)-propane	Dog			5000	D	57
290	1-(3,4-Dihydroxyphenyl)-1-oxo-2-(β-phenylethylamino)-propane	Dog			300	D	57
291	1-(3,4-Dihydroxyphenyl)-1-oxo-2-(α,α-dimethyl-β-phenylethylamino)-propane	Dog			1500	D	57
292	1-(3,4-Dihydroxyphenyl)-1-oxo-2-(γ-phenylpropylamino)-propane	Dog			90	D	57
293	1-(3,4-Dihydroxyphenyl)-1-oxo-2-(α-methyl-γ-phenylpropylamino)-propane	Dog			65	D	57
294	1-(3,4-Dihydroxyphenyl)-1-oxo-2-isopropylamino-butane	Dog			650	D	57
295	1-(3,4-Dihydroxyphenyl)-1-oxo-2-(α-methyl-γ-phenylpropylamino)-butane	Dog			1000	I	57
	Hydroxyphenyl Ethylenediamines						
296	m-Hydroxyphenyl-ethylenediamine (Nu 1896)	Guinea pig	20,000	D			36
297	1-(m-Hydroxyphenyl)-N^2-methyl-ethylenediamine (Nu 1683)	Guinea pig	2000	D			36
298	d-1-(m-Hydroxyphenyl)-N^2-methyl-ethylenediamine (Nu 2013)	Guinea pig	1000	D			36
299	l-1-(m-Hydroxyphenyl)-N^2-methyl-ethylenediamine (Nu 2014)	Guinea pig	4000	D			36
300	3,4-Dihydroxyphenyl-ethylenediamine (Nu 1825)	Guinea pig	1000-2000	D			36
301	1-(3,4-Dihydroxyphenyl)-N^2-methyl-ethylenediamine (Nu 1408)	Guinea pig	100-400	D			36
	Diphenylethylamines and Related Compounds						
302	1,2-Diphenylethylamine	Dog			5,000-15,000	C	121
303		Guinea pig		C			
304	N-Methyl-1,2-diphenylethylamine	Guinea pig		C			121
305	N-Ethyl-1,2-diphenylethylamine	Dog			5,000-15,000	C	121
306		Guinea pig		(D)			
307	N-Propyl-1,2-diphenylethylamine	Guinea pig		C			121
308	N-Isopropyl-1,2-diphenylethylamine	Guinea pig		C			121
309	N-Isobutyl-1,2-diphenylethylamine	Guinea pig		C			121
310	1,2-Di-(p-methoxyphenyl)-ethylamine	Guinea pig		C			121
311	N-Ethyl-1,2-di-(p-methoxyphenyl)-ethylamine	Guinea pig		C			121
312	1-Methyl-2,6-di-(p-methoxyphenylethyl)-piperidine	Guinea pig		D			122
313	1,3-Diphenyl-2-amino-propanol (Ephetonin)	Cat			4000	(D)	34,50
	Aliphatic Amines						
314	Methylamine	Cat				(D)	61,62
315		Rabbit				(D)	
316	Ethylamine	Cat				(D)	61,62
317		Rabbit				(D)	
318	Amylamine	Guinea pig		C			123
319	Isoamylamine	Cat				(C)	59,61,62
320		Rabbit				(C)	
321	1-Hexylamine	Guinea pig		I			124
322	2-Hexylamine	Guinea pig		I			124

134. SYMPATHOMIMETIC AMINES AND RELATED DRUGS ACTING ON THE BRONCHI (Continued)
A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect: Local mμg/ml	Effect: Local Action	Effect: Systemic μg/kg	Effect: Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Aliphatic Amines (concluded)						
323	3-Methyl-1-hexylamine	Guinea pig		I			124
324	2-Methyl-2-hexylamine	Guinea pig		I			124
325	3-Methyl-2-hexylamine	Guinea pig		I			124
326	4-Methyl-2-hexylamine	Guinea pig		I			124
327	5-Methyl-2-hexylamine	Guinea pig		I			124
328	1-Heptylamine	Guinea pig		I			124
329	2-Heptylamine (Tuamine; Tuaminoheptane)	Guinea pig	250,000	D	5000	I	37,124,125
330	3-Heptylamine	Guinea pig		I			124
331	4-Heptylamine	Guinea pig		I			124
332	2-Methyl-2-heptylamine	Guinea pig	250,000	D			125
333	3-Methyl-2-heptylamine	Guinea pig	250,000	D			125
334	4-Methyl-2-heptylamine	Guinea pig	250,000	D			125
335	5-Methyl-2-heptylamine	Guinea pig	250,000	D			125
336	6-Methyl-2-heptylamine	Guinea pig	250,000	D			125
337	2-Octylamine	Guinea pig	250,000	D			125
338	3-Octylamine	Guinea pig	250,000	D			125
339	2-Methyl-6-methylamino-heptene-2 (Octin)	Dog			1,000-10,000	(D)	10,126
340		Rabbit			1000	D	
	Alicyclic Amines						
341	1-Cyclopentyl-2-amino-ethane	Guinea pig		I			4
342	1-Cyclopentyl-2-amino-propane	Guinea pig		I			4
343	1-Cyclopentyl-2-methylamino-propane	Dog			500-1000	D	127
	Indane Derivatives						
344	2-Amino-indane	Cat			8000	D	7,34
345		Guinea pig			20,000	D	
346	2-Amino-indanol-1	Cat			6000	D	87
347	cis-5-Hydroxy-2-amino-indanol-1	Cat			1000-6000	(D)	34
348	trans-5-Hydroxy-2-amino-indanol-1	Cat			1000-6000	(D)	34
349	6-Hydroxy-2-amino-indanol-1	Cat			5000	(D)	34
350	5,6-Methylenedioxy-2-amino-indanol-1	Cat			5000	(D)	34
	Isoquinolines and Related Compounds						
351	Tetrahydroisoquinoline	Dog			550-950	I	128
352	6-Hydroxy-tetrahydroisoquinoline	Dog			900	C	128
353	5,6-Dihydroxy-tetrahydroisoquinoline	Dog			250-950	D	128
354	6,7-Dihydroxy-tetrahydroisoquinoline	Dog			250-1200	(D)	128
355	6-Methoxy-tetrahydroisoquinoline	Dog			600-1300	(D)	128
356	6-Ethoxy-tetrahydroisoquinoline	Dog			600-850	C	128
357	6,7-Diethoxy-tetrahydriosoquinoline	Dog			700-1000	C	128
358	5-Ethoxy-6-methoxy-tetrahydroisoquinoline	Dog			700-1000	I	128
359	6-Ethoxy-7-methoxy-tetrahydroisoquinoline	Dog			700-1000	D	128
360	6-Methoxy-7-ethoxy-tetrahydroisoquinoline	Dog			700	C	128
361	N-Methyl-tetrahydroisoquinoline	Dog			1000-3500	D	128
362	N-Methyl-6-hydroxy-tetrahydroisoquinoline	Dog			600	D	128
363	N-Methyl-5,6-dihydroxy-tetrahydroisoquinoline	Dog			600	D	128
364	N-Methyl-6,7-dihydroxy-tetrahydroisoquinoline	Dog			250-650	D	128
365	N-Methyl-6-methoxy-tetrahydroisoquinoline	Dog			600-1300	C	128
366	N-Methyl-5,6-dimethoxy-tetrahydroisoquinoline	Dog			700	C	128
367	N-Methyl-6,7-dimethoxy-tetrahydroisoquinoline	Dog			700-1400	I	128
368	N-Methyl-6-ethoxy-tetrahydroisoquinoline	Dog			70-130	D	128
369	N-Methyl-6,7-diethoxy-tetrahydroisoquinoline	Dog			500-1100	(A)	128
370	N-Methyl-5-ethoxy-6-methoxy-tetrahydroisoquinoline	Dog			700-1100	I	128
371	N-Methyl-6-methoxy-7-ethoxy-tetrahydroisoquinoline	Dog			1000	I	128

A = active, but action complex (original literature should be consulted); C = constricts; D = dilates; I = inactive. Parentheses in Columns D and F indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Effect				Reference
			Local		Systemic		
			mμg/ml	Action	μg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Isoquinolines and Related Compounds (concluded)						
372	N-Methyl-6-ethoxy-7-methoxy-tetrahydro-isoquinoline	Dog			1000	(A)	128
373	6,7-Diethoxy-1-(3,4-diethoxybenzyl)-isoquinoline (Perparin)	Cat	1,000-100,000	D			33
374	6,7-Dimethoxy-2-methyl-3,4-dihydroiso-quinolinium chloride (Lodal)	Dog			2000-5000	D	64
375	β-Tetrahydronaphthylamine	Dog			3000	D	7,64
376		Guinea pig			30,000	D	
377	2-(1,2,3,4-Tetrahydro-1-naphthyl)-imidazoline (Tetrahydrozoline)	Guinea pig	100,000-200,000	I			129

Contributor: Hawkins, D. F.

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Inclusion of trade names is for informative purposes only and in no way implies endorsement by The National Academy of Sciences-The National Research Council. For all "effects" included in this table, there is reasonable evidence the drug in fact acted on the bronchial musculature. Where there was evidence that an effect was mediated by the respiratory center or adrenal glands, it was excluded. Similarly, results obtained in protecting guinea pigs against lethal doses of histamine were excluded, unless there was evidence of the relief of bronchospasm. Drug actions influencing only anaphylactic or asthmatic bronchospasm, or other pathological states of the bronchi, were also excluded. Concentrations of drugs are given in μg/ml for local action on isolated preparations, and doses in mg/kg for drugs administered systemically. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted. C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect.

Part I: PARASYMPATHOLYTICS AND LOCAL ANESTHETICS
Drugs are listed alphabetically.

	Antagonist (Synonym)	Active Drug		Species	Antagonist Effect				Reference
		Compound	Effect		Local		Systemic		
					μg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Amylocaine	5-Hydroxytryptamine	C	Cat		A			1
2	Antrenyl (Ba 5473; Diethyl(2-hydroxy-ethyl)methylammonium bromide α-phenyl-cyclohexane-glycollate)	Acetylcholine	C	Guinea pig	0.1-1.0	A			2
3		Pilocarpine	C	Cat			1.0	A	3
4	Atropine (Tropine tropate)	Acetylcholine	C	Man	0.0004-10.0	A			4-7
5			C	Cat	1.0	A	0.01-0.04	A	8,9
6			C	Dog	0.1-10.0	A	0.1-1.0	A	10,11
7			C	Guinea pig	0.001-20.0	A	0.01-1.0	A	12-17
8			C	Monkey		A			18
9			C	Pig		A			19
10			C	Rabbit		A			20
11			C	Frog	16.0	A			21,22
12		Agar	C	Guinea pig	500-1000	I			23
13		Amphetamine	C	Dog		A			24
14		Andromedotoxin	C	Rabbit	10	A			25
15		Arecoline	C	Cat		A			26
16			C	Dog	0.1-10.0	A	0.2-1.0	A	11,26-28
17			C	Rabbit		A			26
18		1-Benzyl-3-β-diethyl-aminoethyl-5,5-diallyl-barbituric acid	C	Cat			1.5	I	29
19		Benzyltrimethylammonium iodide	C	Guinea pig		A			30
20		Carbachol	C	Dog			0.1	A	31
21		Carbaminoyl-β-methylcholine	C	Dog			0.1	A	32
22		Coniine	C	Guinea pig	10	(A)			8
23		Curarine	C	Cat		I			33
24			C	Guinea pig				A	34
25		Cytisine	C	Guinea pig	10	I			8
26		Diethylaminoethanol	C	Guinea pig		I			35
27		Diethylmorphine	C	Dog		I		I	26,28
28		Diisopropylfluoro-phosphate	C	Guinea pig	0.01	A			36
29		N-Dimethyl-hexa-hydro-isonicotinic acid methyl ester iodide	C	Cat			0.4	A	37
30		Ephedrine	D	Cat		I			26
31			D	Dog		I		I	26,28
32			D	Rabbit		I			26
33			C	Rabbit	2	I			38,39

Part I: PARASYMPATHOLYTICS AND LOCAL ANESTHETICS (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist (Synonym)	Active Drug: Compound	Active Drug: Effect	Species	Antagonist Effect: Local: µg/ml	Local: Action	Systemic: mg/kg	Systemic: Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
34	Atropine (Tropine tropate) (continued)	ψ-Ephedrine	D	Cat		I			26
35			D	Dog		I		I	26,28
36			D	Rabbit		I			26
37		Epinephrine	D	Cat		I	3	1	26.73
38			D	Dog		I		I	26,28
39			D	Guinea pig	1-100	I			8
40			D	Rabbit		I			26
41		Ergot	C	Dog				A	40
42		Ethylcholine	C	Dog		A			41
43			C	Guinea pig		A			41
44		Furmethide	C	Guinea pig		A			30
45		Hexamethonium	C	Guinea pig	1-10	I			8
46		Histamine	C	Man			0.01	(A)	42
47			C	Cat		(A)	10	I	43,44
48			C	Dog		A	1-2	(A)	24,28, 45-47
49			C	Guinea pig	1-1000	A	0.1-40.0	A	12,16, 48-55
50		5-Hydroxytryptamine	C	Cat			0.3	(A)	9,56
51			C	Guinea pig		A	0.3-1.3	A	57,58
52		Kalmia	C	Guinea pig		I			59
53		Lobeline	C	Guinea pig	1-10	I			8
54		Methacholine	C	Man			0.01	A	42
55			C	Cat		A			24
56			C	Dog		A	0.2	A	24,46,61
57			C	Guinea pig			0.01-3.0	A	16,50,51,62
58		Miotine	C	Cat				A	63
59		Morphine	C	Dog		I		I	26,28
60		Muscarine	C	Cat		A	0.5-20.0	A	44,64,65
61			C	Dog			0.2-0.5	A	40,66
62			C	Guinea pig				A	67
63			C	Pig	3-200	A			68,69
64			C	Frog		A			22
65		Nicotine	C	Cat	1	A			8
66			C	Guinea pig			0.1-1.3	A	16
67			D	Guinea pig	1-100	A			8
68		Norepinephrine	D	Guinea pig	1-100	I			8
69		Peptone	C	Dog			0.2	I	46
70			C	Guinea pig	500	A			23,70
71		Physostigmine	C	Cat		A	0.3	A	26,64,71
72			C	Dog	0.1-10	A	0.4	A	11,24,26,28
73			C	Guinea pig	0.01	A			36
74			C	Rabbit		A	0.5	A	26,40
75		Pilocarpine	C	Cat		A	0.5-3.0	A	26,66,72, 74,75
76			C	Dog	2	A	0.1-0.8	A	24,26,28, 40,47, 76-80
77			C	Guinea pig		A			81,82
78			C	Ox	20-30	A			84
79			C	Pig	30-200	A			68,69
80			C	Rabbit		A	3.0	A	24,26,85
81			C	Turtle			5.0	A	40
82			C	Frog	20	A			22
83		Pyrilamine	C	Guinea pig	10	I			60
84		Tetraethylpyrophosphate	C	Guinea pig	0.01	A			36
85		Tetramethylammonium chloride	C	Guinea pig	1	A			8

Part 1: PARASYMPATHOLYTICS AND LOCAL ANESTHETICS (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist (Synonym)	Active Drug		Species	Antagonist Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
86	Atropine (Tropine	d-Tubocurarine	C	Dog			0.2	I	46
87	tropate)(concluded)	Xysmalobinum	C	Cat				I	86
88	Bellafoline[1]	Histamine	C	Man			0.01	I	42
89		Methacholine	C	Man			0.01	A	42
90	bis-[1-(Carbo-β-diethyl-	Furmethide	C	Guinea pig			50	A	87
91	aminoethoxy)-1-phenyl-cyclopentane]-ethane di-sulphonate (SKF 769 J_2)	Histamine	C	Guinea pig			75	(A)	87
92	Dibucaine (Nupercaine)	Histamine	C	Guinea pig			5	I	54
93	Dibutoline (Dimethyl-	Histamine	C	Guinea pig		I	100	I	50,88
94	ethyl-β-hydroxyethyl-	Methacholine	C	Guinea pig			0.6	A	50
95	ammonium sulphate di-n-butyl carbamate)	Pilocarpine	C	Guinea pig		A			88
96	2,2-Diphenyl-4-	Acetylcholine	C	Guinea pig		A			57
97	diisopropylamino-butyramide methyl-iodide (R 79)	5-Hydroxytryptamine	C	Guinea pig		I			57
98	Homatropine sulphuric ester	Pilocarpine	C	Ox	400	I			89
99	d-Hyoscine[2] (Scopine tropate)	Muscarine	C	Pig		A			69
100	d-Hyoscyamine[3] (Tropine tropate)	Muscarine	C	Pig		A			69
101	l-Hyoscyamine[4]	Muscarine	C	Cat				A	64
102			C	Pig		A			69
103	Lidocaine (Lignocaine; Xylocaine)	5-Hydroxytryptamine	C	Cat		A			1
104	Methantheline (Banthine; β-Diethylaminoethyl	Acetylcholine	C	Guinea pig	0.05-10.0	A			51,91
105	xanthene-9-carboxylate	Histamine	C	Guinea pig	10	(A)	6	I	51,91,92
106	methobromide	Methacholine	C	Guinea pig			0.5-3	A	51,92
107	Novatropine	Acetylcholine	C	Guinea pig	0.05-0.1	A			12
108			C	Frog	0.3	(A)			99
109		Histamine	C	Guinea pig	10	I	2-3	A	12,93
110	Procaine (Novocaine;	Acetylcholine	C	Man	50	I			4
111	P.A.D.; p-Amino-		C	Guinea pig		A			94
112	benzoyl-diethylamino-ethanol)	Diisopropylfluoro-phosphate	C	Dog			20-40	A	95
113		Histamine	C	Man		I			96
114			C	Guinea pig		(A)		(A)	4,52,54,94
115		Hydroxyphenyl-benzyl trimethylammonium dimethylcarbamate	C	Dog			100	A	95
116		5-Hydroxytryptamine	C	Cat		A			1
117		Physostigmine	C	Dog			100-200	A	95
118		Pilocarpine	C	Guinea pig		A			94
119	Propantheline	Acetylcholine	C	Guinea pig			0.2-10.0	A	16
120	(Pro-Banthine)	Histamine	C	Guinea pig			0.2-10.0	A	16
121		5-Hydroxytryptamine	C	Guinea pig			1.0-10.0	A	16
122		Methacholine	C	Guinea pig			0.1-10.0	A	16
123		Methyl-furmethide	C	Guinea pig			0.2-2.0	A	16
124		Nicotine	C	Guinea pig			1.0-10.0	A	16
125	Scopolamine (l-Hyoscine;	Acetylcholine	C	Dog	0.1-10	A			11
126	Scopine tropate)	Arecoline	C	Dog	0.1-10	A			11
127		Histamine	C	Man			0.005-0.01	(A)	42
128		Methacholine	C	Man			0.005-0.01	A	42
129		Muscarine	C	Cat				A	64
130			C	Pig		A			69
131		Physostigmine	C	Dog	0.1-10	A			11

/1/ Belladonna alkaloids. /2/ Dextro isomer of scopolamine. /3/ Dextro isomer of atropine. /4/ Levo isomer of atropine.

Part I: PARASYMPATHOLYTICS AND LOCAL ANESTHETICS (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist (Synonym)	Active Drug		Species	Antagonist Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
132	Scopolamine butylbromide	Acetylcholine	C	Dog			0.5	A	97
133	(Buscopan; Scopolamine-N-bromobutylate)	Histamine	C	Dog				I	97
134			C	Guinea pig			20	A	97
135		Pilocarpine	C	Dog			0.01	A	97
136	Scopolamine methylbromide (Epoxymethamine bromide; Pamine; Scopolamine-N-bromomethylate)	Acetylcholine	C	Guinea pig		A			98
137		Histamine	C	Guinea pig		A			98
138	Syntropan (3-Diethylamino-2, 2-dimethylpropyl dl-tropate)	Acetylcholine	C	Guinea pig	5	A			12
139		Histamine	C	Guinea pig	10	I	30	I	12,54
140		Pilocarpine	C	Cat			12	A	74
141	Tetracaine (Amethocaine)	5-Hydroxytryptamine	C	Cat		A			1

Contributor: Hawkins, D. F.

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Part II: ANTICHOLINESTERASES

Drugs are listed alphabetically. C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug		Species	Antagonist or Potentiator Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Benzoylcholine	Acetylcholine	C	Cat	3-10	P			1,2
2			C	Cat	100	A			1,2
3			C	Dog		P			1
4			C	Rabbit	10	P			2
5			C	Rabbit	100	A			2
6	Diisopropylfluorophosphate (DFP)	Acetylcholine	C	Guinea pig	1.0	P			3
7	Miotine ([α-(m-Hydroxyphenyl)-ethyl]dimethylamine methylcarbamate)	Acetylcholine	C	Cat			0.5	P	4
8		Epinephrine	D	Cat				I	4
9	Neostigmine (Prostigmine)	Methacholine	C	Man			0.005	P	5
10	Physostigmine (Eserine)	Acetylcholine	C	Man	0.1-1.0	P			6, 7
11			C	Dog			0.1-0.6	P	8
12			C	Guinea pig	0.1-5.0	P	1.0	P	3,9-11
13			C	Monkey		P			12
14			C	Rabbit		P			13
15			C	Frog	10	P			14
16		Histamine	C	Dog			0.0025	I	15
17			C	Guinea pig			0.75	P	16
18		Nicotine	C	Cat	0.1-1.0	P			17
19			C	Guinea pig	0.1	(P)			17
20	Tetraethylpyrophosphate (TEPP)	Acetylcholine	C	Guinea pig	0.1	P			3

Contributor: Hawkins, D. F.

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Part III: ANTIHISTAMINES

Drugs are listed to illustrate, as far as possible, the relationship between chemical structure and pharmacological action. C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug		Species	Antagonist or Potentiator Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Phenol Ethers								
1	(m-Methylphenyl-oxo-ethyl)-amine (JL 474)	Histamine	C	Guinea pig			10	I	1
2	(p-Methylphenyl-oxo-ethyl)-amine (JL 478)	Histamine	C	Guinea pig			10	I	1
3	(p-Methoxyphenyl-oxo-ethyl)-amine (JL 499)	Histamine	C	Guinea pig			10	I	1
4	(3, 4-Dimethylphenyl-oxo-ethyl)-amine (JL 912)	Histamine	C	Guinea pig			10	I	1
5	(p-Methylphenyl-oxo-ethyl)-methylamine (JL 950)	Histamine	C	Guinea pig			10	I	1
6	(2-Isopropyl-5-methyl-phenyl-oxo-ethyl)-ethylamine (1482 F)	Histamine	C	Guinea pig		A		I	2
7	(o-Methylphenyl-oxo-ethyl)-(β-hydroxy-ethyl)-amine (JL 504)	Histamine	C	Guinea pig			10	I	1
8	(p-Methylphenyl-oxo-ethyl)-(β-hydroxyethyl)-amine (JL 725)	Histamine	C	Guinea pig			10	I	1
9	(Phenyl-oxo-ethyl)-dimethylamine (JL 413)	Histamine	C	Guinea pig			10	A	1
10	(o-Methylphenyl-oxo-ethyl)-dimethylamine (JL 963)	Histamine	C	Guinea pig			10	A	1
11	(2, 5-Dimethylphenyl-oxo-ethyl)-diethylamine (1655 F)	Histamine	C	Guinea pig		A			2
12	(2-Isopropyl-5-methyl-phenyl-oxo-ethyl)-di-ethylamine (Thymoxy-ethyldiethylamine; 929 F)	Histamine	C	Dog			40	A	3
13			C	Guinea pig	1-10	A	2.5-25	A	1,2,4,5
14	(p-Methylphenyl-oxo-ethyl)-phenylamine (JL 956)	Histamine	C	Guinea pig			5	I	1
15	N-[p-(tert.-Octyl)-phe-noxy-ethyl-oxo-ethyl]-morpholine (S 150)	Histamine	C	Guinea pig		A			6
16	Di-(p-methylphenyl-oxo-ethyl)-amine (JL 477)	Histamine	C	Guinea pig			4	A	1
17	Di-(3, 4-dimethylphenyl-oxo-ethyl)-amine (JL 765)	Histamine	C	Guinea pig			2	A	1
18	Di-(o-methylphenyl-oxo-ethyl)-methylamine (JL 951)	Histamine	C	Guinea pig			8	I	1
19	Tri-(o-methylphenyl-oxo-ethyl)-amine (JL 959)	Histamine	C	Guinea pig			10	A	1
	Benzhydryl Ethers								
20	β-Aminoethyl benzhydryl ether	Histamine	C	Guinea pig			25	A	5

Part III: ANTIHISTAMINES (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug: Compound	Active Drug: Effect	Species	Local: µg/ml	Local: Action	Systemic: mg/kg	Systemic: Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Benzhydryl Ethers (Continued)								
21	β-Methylaminoethyl benzhydryl ether (S 59)	Histamine	C	Dog			2-5	A	6
22			C	Guinea pig		A	6-12.5		5,6
23		Pilocarpine	C	Guinea pig		A			6
24	β-Dimethylaminoethyl benzhydryl ether (Diphenhydramine; Benadryl)	Histamine	C	Man		A	0.5-1.0	A	7,8,9
25			C	Dog			2-5	A	6,10
26			C	Guinea pig	0.005-50.0	A	0.005-12.5	A	5,11,12-23,25
27		Acetylcholine	C	Guinea pig	4	A			15
28		Methacholine	C	Man			0.5-1.0	A	8,9
29			C	Dog			1	A	10
30			C	Guinea pig			25-33	A	26,27
31		Pilocarpine	C	Guinea pig		A			6
32		β-Pyridylethylamine	C	Guinea pig	0.005	A			12
33		d-Tubocurarine	C	Dog			1	A	10
34	Diphenhydramine oxalate	Histamine	C	Guinea pig			2.7	A	11
35	Diphenhydramine succinate	Histamine	C	Guinea pig			2.0	A	11
36	β-Isopropylaminoethyl benzhydryl ether (S 82)	Histamine	C	Dog			2-5	A	6
37			C	Guinea pig		A	6.0-12.5	A	5,6
38		Pilocarpine	C	Guinea pig		A			6
39	β-Diethylaminoethyl benzhydryl ether	Histamine	C	Guinea pig			6.0-12.5	A	5
40	β-n-Butylaminoethyl benzhydryl ether	Histamine	C	Guinea pig			12.5	I	5
41	β-Di-n-butylaminoethyl benzhydryl ether	Histamine	C	Guinea pig			50	(A)	5
42	β-Dicyclohexylaminoethyl benzhydryl ether	Histamine	C	Guinea pig			50	(A)	5
43	β-(β-Diethylaminoethyl-oxo)-ethyl benzhydryl ether	Histamine	C	Guinea pig			50	A	5
44	β-(β-Hydroxyethylmethyl-amino)-ethyl benzhydryl ether (S 161)	Histamine	C	Guinea pig		A			6
45	β-Piperidinoethyl benzhydryl ether	Histamine	C	Guinea pig			1.5-12.5	A	5
46	β-Morpholinoethyl benzhydryl ether	Histamine	C	Guinea pig			3.0-12.5	A	5
47	β-(β-Morpholinoethyl-amino)-ethyl benzhydryl ether	Histamine	C	Guinea pig			25	A	5
48	Diethylaminopropyl benzhydryl ether	Histamine	C	Guinea pig			6-12.5	A	5
49	β-Methyl-β-morpholino-propyl benzhydryl ether	Histamine	C	Guinea pig			25	A	5
50	6-Morpholinohexyl benzhydryl ether	Histamine	C	Guinea pig			50	A	5
51	(β-Benzhydryl-oxo-ethyl)-trimethylammonium iodide (S 92)	Histamine	C	Dog			2-5	A	6
52			C	Guinea pig		A	0.5	A	6,11
53	(β-Benzhydryl-oxo-ethyl)-trimethylammonium methylsulphonate	Histamine	C	Guinea pig			1.3	A	11
54	(β-Benzhydryl-oxo-ethyl)-trimethylammonium p-toluensulphonate (S 154)	Histamine	C	Dog			3-5	A	6
55			C	Guinea pig		A	2.8	A	6,11

Part III: ANTIHISTAMINES (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug		Species	Antagonist or Potentiator Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Benzhydryl Ethers (concluded)								
56	(β-Benzhydryl-oxo-ethyl)-dimethylethylammonium bromide	Histamine	C	Guinea pig			1.8	A	11
57	(β-Benzhydryl-oxo-ethyl)-dimethylethylammonium p-toluenesulphonate (S 158)	Histamine	C	Dog			5	A	6
58			C	Guinea pig		A	1.7	A	6,11
59	4-(β-Benzhydryl-oxo-ethyl)-4-methyl-morpholinium p-toluenesulphonate (S 157)	Histamine	C	Dog			5	A	6
60			C	Guinea pig		A			6
61	4-Chloro-benzhydryl tropine ether (SL 6057)	Histamine	C	Guinea pig	10	A	1-10	A	28
62		Acetylcholine	C	Guinea pig		(A)			28
63	4-Chloro-benzhydryl tropine ether methylbromide (SL 6058)	Histamine	C	Guinea pig			2-10	A	28
64	4, 4'-Dichlorobenzhydryl-β-morpholinoethyl ether	Histamine	C	Guinea pig			25	A	5
	Benzhydryl Amines								
65	β-Aminoethyl benzhydryl amine	Histamine	C	Guinea pig			50	I	5
66	β-Diethylaminoethyl benzhydryl amine	Histamine	C	Guinea pig			25	I	5
67	β-Morpholinoethyl benzhydryl amine	Histamine	C	Guinea pig			25	I	5
68	γ-Diethylaminopropyl benzhydryl amine	Histamine	C	Guinea pig			50	I	5
69	N-Methyl-N'-benzhydryl-piperazine (Cyclizine; Marezine; 47-83)	Histamine	C	Guinea pig	0.4	A	10	A	16,19,29
70	N-Methyl-N'-(4-chloro-benzhydryl)-piperazine (Chloro-cyclizine; Perazil; Histantin; 47-282)	Histamine	C	Man	0.2	A			7
71			C	Guinea pig	0.1-0.5	A	2.5-10	A	16,19,21
	Ethylenediamines								
72	N-Phenyl-N-methyl-N', N'-diethyl-ethylenediamine (1335 F)	Histamine	C	Guinea pig		I			2
73	N-Phenyl-N-ethyl-N', N'-dimethyl-ethylenediamine (RP 2325)	Histamine	C	Guinea pig			0.2-20.0	A	30-33
74	N-Phenyl-N-ethyl-N', N'-diethyl-ethylenediamine (1571 F)	Histamine	C	Guinea pig	1-10	A	3-25	A	2,5,11,32, 33
75	N-(o-Methylphenyl)-N-ethyl-N', N'-diethyl-ethylenediamine (1599 F)	Histamine	C	Guinea pig		I			2
76	N-Phenyl-N-benzyl-N', N'-dimethyl-ethylenediamine (Antergan; Lergitin; RP 2339)	Histamine	C	Cat			4	A	34
77			C	Guinea pig	0.1	A	0.5-20	A	31-33,35-38
78		Acetylcholine	C	Guinea pig			<50	I	33,37
79		Agmatine	C	Guinea pig		A			39
80		Amylamine	C	Guinea pig		A			39
81		Cadaverine	C	Guinea pig		A			39
82		Clupeine	C	Guinea pig		A			39
83		Guanidine	C	Guinea pig		A			39
84		Putrescine	C	Guinea pig		A			39
85		Sodium nucleinate	C	Guinea pig		A			39
86	N-Phenyl-N-(2-thenyl)-N', N'-dimethyl-ethylenediamine (Methaphenilene; Diatrin; W-50)	Histamine	C	Guinea pig		A	0.05-1.0	A	40

Part III: ANTIHISTAMINES (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug Compound	Active Drug Effect	Species	Local μg/ml	Local Action	Systemic mg/kg	Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Ethylenediamines (continued)								
87	N-Benzyl-N-(2-pyrimidyl)-N', N'-dimethyl-ethylene-diamine (Hetramine)	Histamine	C	Guinea pig			0.3-12.0	A	19,25,41-43
88	N-(p-Methoxybenzyl)-N-(2-pyrimidyl)-N', N'-dimethyl-ethylene-diamine (Thonzylamine; Anahist; Neohetramine)	Histamine	C	Guinea pig	0.02-2.0	A	3.5-10.0	A	19,41,42, 44,45
89	N-(p-Methoxybenzyl)-N-(2-thiazolyl)-N', N'-dimethyl-ethylene-diamine (194 B)	Histamine	C	Guinea pig			5	A	19
90	N-Benzyl-N-(β-picolinyl)-N', N'-dimethyl-ethylenediamine (74)	Histamine	C	Guinea pig			10	A	30
91	N-Benzyl-N-(γ-picolinyl)-N', N'-dimethyl-ethylenediamine (106)	Histamine	C	Guinea pig			1.0	A	30
92	N-(1-Naphthyl)-N-benzyl-N', N'-dimethyl-ethylenediamine (T 1)	Histamine	C	Guinea pig			5.6	A	31
93	N-(1-Naphthyl)-N-benzyl-N', N'-diethyl-ethylenediamine (T 2)	Histamine	C	Guinea pig			16	(A)	31
94	N-(2-Naphthyl)-N-benzyl-N', N'-dimethyl-ethylenediamine (T 3)	Histamine	C	Guinea pig			16	(A)	31
95	N-(2-Naphthyl)-N-benzyl-N', N'-diethyl-ethylene-diamine (T 4)	Histamine	C	Guinea pig			16	(A)	31
96	N-(1-Naphthyl)-N-ethyl-N', N'-dimethyl-ethylenediamine (T 5)	Histamine	C	Guinea pig			16	(A)	31
97	N-(1-Naphthyl)-N-ethyl-N', N'-diethyl-ethylenediamine (T 6)	Histamine	C	Guinea pig			16	(A)	31
98	N-(2-Naphthyl)-N-ethyl-N', N'-dimethyl-ethylenediamine (T 7)	Histamine	C	Guinea pig			16	(A)	31
99	N-(2-Naphthyl)-N-ethyl-N', N'-diethyl-ethylene-diamine (T 8)	Histamine	C	Guinea pig			16	(A)	31
100	N-Benzyl-N-(2-pyridyl)-	Histamine	C	Man	50	A	0.5-1.0	A	8,46
101	N', N'-dimethyl-		C	Dog			0.1-3.0	A	10,35
102	ethylenediamine (Tripelennamine; Pyribenzamine; U-95)		C	Guinea pig	0.03-1.7	A	0.1-10.0	A	13,16,19,22, 25,28,30, 35,41,42, 44, 47-54
103		Acetylcholine	C	Dog			0.1-0.3	I	35
104		Curarine	C	Dog			2	A	10
105		Methacholine	C	Dog			2	I	10
106		d-Tubocurarine	C	Dog			2	A	10
107	N-(p-Methoxybenzyl)-N-(2-pyridyl)-N', N'-	Histamine	C	Man	0.0004-10.0	A			7, 21,55-57
108	dimethyl-ethylene-diamine (Mepyramine; Pyranisamine; Pyrilamine; Neoantergan;		C	Guinea pig	0.00025-5.0	A	0.001-2.5	A	4,12,16, 21,25, 54,58-62
109	RP 2786)	Acetylcholine	C	Guinea pig			1-3	A	61

Part III: ANTIHISTAMINES (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug		Species	Antagonist or Potentiator Effect				Reference
		Compound	Effect		Local		Systemic		
					μg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
				Ethylenediamines (continued)					
110	N-(p-Methoxybenzyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylene-diamine (Mepyramine; Pyranisamine; Pyrilamine; Neoantergan; RP 2786) (concluded)	Epinephrine	D	Guinea pig		I			63
111		5-Hydroxytryptamine	C	Guinea pig		I	1	(A)	61,64,65
112		Methacholine	C	Guinea pig			3-6	A	61
113		Methyl-furmethide	C	Guinea pig			1-3	A	61
114		Nicotine	C	Guinea pig			1-3	(A)	61
115			D	Guinea pig		A			63
116		Norepinephrine	D	Guinea pig		(P)			63
117		Pentamidine	C	Guinea pig			2.5	A	66
118		β-Pyridyl-ethylamine	C	Guinea pig	0.0004	A			12
119	N-(p-Chlorobenzyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylene-diamine (Chlorneo-antergan)	Histamine	C	Guinea pig			1	A	19
120	N-(p-Bromobenzyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylene-diamine (Hibernon; p-Bromotripelen-namine)	Histamine	C	Guinea pig	0.01-2.0	A			67
121	N-(p-Fluorobenzyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylene-diamine	Histamine	C	Guinea pig			1	A	19
122	N-(2-Thenyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylene-diamine (Metha-pyrilene; Thenylene; Histadyl; W-53)	Histamine	C	Guinea pig			0.025-3.0	A	16,19,22,44
123	N-(5-Chloro-2-thenyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylene-diamine (Chloro-pyrilene; Chlorothen)	Histamine	C	Guinea pig			2.5-3.0	A	16,19,44,48
124	N-(5-Bromo-2-thenyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylene-diamine (Bromothen)	Histamine	C	Guinea pig			3	A	19
125	N-(3-Thenyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylene-diamine-(Thenyldiamine; Thenfadil)	Histamine	C	Guinea pig		A	0.04-0.17	A	49
126	N-(2-Chloro-3-thenyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylene-diamine (WIN 2875)	Histamine	C	Guinea pig		A	0.4-0.9	A	49
127	N-(2-Bromo-3-thenyl)-N-(2-pyridyl)-N', N'-dimethyl-ethylene-diamine (WIN 2876)	Histamine	C	Guinea pig		A	0.4-0.9	A	49
128	N-(2-Furfuryl)-N-(2-pyridyl)-N', N'-di-methyl-ethylene-diam-ine (Methafurylene)	Histamine	C	Guinea pig	0.01	A	1-2	A	52
129	N^1-Phenyl-N^1-benzyl-N^2,N^2-dimethyl-2-methylethylene-diamine	Histamine	C	Guinea pig				A	68

Part III: ANTIHISTAMINES (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug		Species	Antagonist or Potentiator Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Ethylenediamines (concluded)								
130	N^1-Phenyl-N^1-benzyl-N^2,N^2-diethyl-2-methyl-ethylenediamine	Histamine	C	Guinea pig				A	68
	Phenothiazines and Related Compounds								
131	N-Dimethylaminoethyl-phenothiazine (RP 3015)	Histamine	C	Dog			1.0	A	69
132			C	Guinea pig			0.1-8.0	A	19,25,69
133	N-Diethylaminoethyl-phenothiazine (Diethazine; Diparcol; 2987 RP)	Diisopropylfluoro-phosphate	C	Dog			8.5	A	70
134		Pilocarpine	C	Dog			10.0	A	70
135	N-(β-Dimethylamino-propyl)phenothiazine (Promethazine; Phenergan; RP 3277)	Histamine	C	Man		A	0.5-1.0	A	7,71
136			C	Dog			1.0	A	69
137			C	Guinea pig	5	A	0.2-10.0	A	19,21,25, 26,28,69, 72-75
138		5-Hydroxytryptamine	C	Guinea pig		I	1-3	A	64, 65
139		Methacholine	C	Man			0.5-1.0	A	71
140			C	Guinea pig			6.0	A	26
141	N-(γ-Dimethylamino-β, β-dimethyl-propyl)-phenothiazine (RP 3300)	Histamine	C	Guinea pig				I	38
142	N-Dimethylaminopropyl-3-chlorophenothiazine (Chlorpromazine; Largactil)	Histamine	C	Guinea pig			10-40	A	61,72-74
143		Acetylcholine	C	Guinea pig			5-10	A	61
144		5-Hydroxytryptamine	C	Guinea pig			5-10	A	61
145		Methacholine	C	Guinea pig			10	(A)	61
146		Methyl-furmethide	C	Guinea pig			10	A	61
147		Nicotine	C	Guinea pig			5-10	A	61
148	N-Methylpiperidyl-3-methyl-phenothiazine (Lacumin)	Histamine	C	Guinea pig				A	76
149	N-Pyrrolidineethyl-pheno-thiazine (Pyrathiazine; Pyrrolazote; 1-WBR-86)	Histamine	C	Guinea pig			2-12	A	19,44,47
150	N-Dimethylaminoethyl-1-methoxyphenothiazine (RP 3298)	Histamine	C	Guinea pig				A	38
151	N-(α-Methyl-β-dimethyl-aminoethyl)-1-methoxy-phenothiazine (RP 3299)	Histamine	C	Guinea pig				A	38
152	N-Dimethylaminoethyl-thionodiphenylamine (RP 3283)	Histamine	C	Guinea pig				A	38
153	N-Dimethylaminoethyl-sulphonodiphenylamine (RP 3289)	Histamine	C	Guinea pig				A	38
	Miscellaneous								
154	2-Dimethylaminoethoxy-diphenylmethane (C 5581 H)	Histamine	C	Guinea pig			5	A	19
155	2-Dimethylaminoethoxy-4-chloro-diphenyl-methane (01780)	Histamine	C	Guinea pig			10	A	19
156	α-Dimethylaminoethoxy-α-(2-pyridyl)-ethyl-benzene (Decapryn; Doxylamine)	Histamine	C	Guinea pig			5	A	19,44
157	1-Phenyl-1-(2-pyridyl)-3-dimethylamino-propane (Prophenpyrid-amine; Inhiston; Trimeton)	Histamine	C	Guinea pig	0.02	A	0.5-5	A	19,45,77

Part III: ANTIHISTAMINES (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug Compound	Active Drug Effect	Species	Antagonist or Potentiator Effect: Local µg/ml	Local Action	Systemic mg/kg	Systemic Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(G)
	Miscellaneous (concluded)								
158	1-Phenyl-1-(2-pyridyl)-3-dimethylamino-propane p-aminosalicylate (Avil; 11513c)	Histamine	C	Guinea pig			0.1-10.0	A	77
159	1-(p-Chlorphenyl)-1-(2-pyridyl)-3-dimethylamino-propane (Chlorpheniramine; Chlorprophenpyridamine; Chlor-Trimeton)	Histamine	C	Guinea pig			0.05-10.0	A	19,28,60
160	N'-Benzyl-N-methyl-piperazine (46-125)	Histamine	C	Guinea pig		(A)			16
161	N'-Benzyl-N-ethyl-piperazine (46-126)	Histamine	C	Guinea pig		(A)			16
162	N'-Benzyl-N-(n-lauryl)-piperazine (895)	Histamine	C	Guinea pig		I			16
163	4-Dimethylamino-N-phenylpiperidine (Irenal)	Histamine	C	Dog		A	1-2	A	78
164	1,2-Diphenyl-4-piperidyl-1-butene (01003)	Histamine	C	Guinea pig				A	19
165	1-Methyl-4-amino-N'-phenyl-N'-(2'-thenyl)-piperidine (Sandosten)	Histamine	C	Guinea pig			0.08-0.15	A	79
166		5-Hydroxytryptamine	C	Guinea pig			0.3	A	79
167	2-(N-Phenyl-N-benzyl-aminomethyl)imidazoline (Antazoline; Antistine; Antastan; 5512-M)	Histamine	C	Man		A			21
168			C	Guinea pig	0.005-50.0	A	0.0025-15.0	A	13,17,19,21,67,80,81
169	2-(1,2,3,4-Tetrahydro-1-naphthyl)-imidazoline (Tetrahydrozoline Tyzine)	Histamine	C	Guinea pig	100-200	A			82
170	trans-1-(4'-Methyl-phenyl)-1-(2'-pyridyl)-3-pyrrolidinoprop-1-ene hydrochloride (295 C 51)	Histamine	C	Guinea pig			0.01-1.0	A	60
171	trans-1-(4'-Chloro-phenyl)-1-(2'-pyridyl)-3-pyrrolidinoprop-1-ene maleate (405 C 49)	Histamine	C	Guinea pig			0.09-2.5	A	60
172	2-Methyl-9-phenyl-2,3-dihydro-1-pyridindene (Nu 1326)	Histamine	C	Guinea pig			6-12		23
173	2-Methyl-9-phenyl-2,3,4,9-tetrahydro-1-pyridindene (Phenindamine; Thephorin; Nu 1504)	Histamine	C	Cat			1.0	A	23,83
174			C	Guinea pig			0.25-10.0	A	19,23,75,83
175		Acetylcholine	C	Cat			1.0	A	23
176	2-Methyl-9-phenyl-2,3,4,4a,9,9a-hexahydro-1-pyridindene (Nu 1525)	Histamine	C	Guinea pig			30	A	23

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Part IV: ERGOT DERIVATIVES

Drugs are listed alphabetically. C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug		Species	Antagonist or Potentiator Effect				Reference
		Compound	Effect		Local		Systemic		
					μg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	1-Acetyl-d-lysergic acid diethylamide	5-Hydroxytryptamine	C	Cat			0.015-0.03	A	1
2	2-Bromo-d-lysergic acid diethylamide	5-Hydroxytryptamine	C	Cat			0.015-0.03	A	1
3	Dihydroergocornine	Histamine	C	Man			0.003-0.01	A	2
4		Methacholine	C	Man			0.003-0.01	A	2
5	Dihydroergotamine	Epinephrine	D	Guinea pig	0.3-5.0	A			3
6		5-Hydroxytryptamine	C	Cat		A			4
7			C	Guinea pig		A	4.0	A	5,6
8		Isoproterenol	D	Guinea pig	0.3-3.0	A			3
9		Lobeline	D	Guinea pig	1.0	I			3
10		Nicotine	D	Guinea pig	0.3-1.0	A			3
11		Norepinephrine	D	Guinea pig	10.0	(A)			3
12	Ergometrine	Epinephrine	D	Guinea pig	1.0	I			3
13		5-Hydroxytryptamine	C	Guinea pig			0.2	I	1
14		Norepinephrine	D	Guinea pig	1.0	I			3
15	Ergotamine	Arecoline	C	Cat		I			8
16			C	Dog		I		I	7,8
17			C	Rabbit		I			8
18		Diethylmorphine	C	Cat		I			8
19			C	Dog		I		I	7,8
20		Ephedrine	D	Dog				I	7
21		ψ-Ephedrine	D	Dog				I	7
22		Epinephrine	D	Cat		I	2.0	P	8,9
23			D	Dog		I	2.0	I	7,8,9
24			D	Guinea pig	0.8-10.0	(A)			3,10
25			D	Rabbit		I			8
26		Histamine	C	Cat		I			8
27			C	Dog		I	5.0	I	7,8
28			C	Guinea pig			1.5	I	11
29			C	Rabbit		I			8
30		5-Hydroxytryptamine	C	Guinea pig		A			5
31		Isoproterenol	D	Guinea pig	0.3-3.0	A			3
32		Morphine	C	Cat		I			8
33			C	Dog		I		I	7,8
34		Nicotine	D	Guinea pig	1.0	A			3
35		Norepinephrine	D	Guinea pig	10	(A)			3
36			D	Guinea pig	40	(P)			3
37		Physostigmine	C	Cat		I			8
38			C	Dog		I		I	7,8
39			C	Rabbit		I			8
40		Pilocarpine	C	Cat		I			8
41			C	Dog		I		I	7,8
42			C	Rabbit		I			8
43	Ergotoxine[1]	Acetylcholine	C	Guinea pig		A			12,13
44		Arecoline	C	Cat		I			8
45			C	Dog		I		I	7,8
46			C	Rabbit		I			8
47		Diethylmorphine	C	Cat		I			8
48			C	Dog		I		I	7,8
49		Ephedrine	D	Cat		I			8
50			D	Dog		I		I	7,8
51			D	Rabbit		I			8

/1/ Contains ergocornine, plus small amounts of ergokryptine and ergocristine.

Part IV: ERGOT DERIVATIVES (Concluded)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug: Compound	Active Drug: Effect	Species	Local: µg/ml	Local: Action	Systemic: mg/kg	Systemic: Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
52	Ergotoxine[1] (concluded)	ψ-Ephedrine	D	Cat		I			8
53			D	Dog		I		I	7,8
54			D	Rabbit		I			8
55		Epinephrine	D	Cat		I	0.3	I	8,14
56			D	Dog		I	0.2-2.0	I	7,8,15
57			D	Guinea pig		(A)			16,17
58			D	Pig		A			18
59			D	Rabbit		I			8
60		Histamine	C	Cat		I			8
61			C	Dog		I		I	7,8
62			C	Rabbit		I			8
63		Morphine	C	Cat		I			8
64			C	Dog		I		I	7,8
65		Muscarine	C	Cat		I			14
66		Nicotine	D	Guinea pig		A			3
67		Norepinephrine	D	Guinea pig		I			3
68		Physostigmine	C	Cat		I			8
69			C	Dog		I		I	7,8
70			C	Rabbit		I			8
71		Pilocarpine	C	Cat		I			8
72			C	Dog		I		I	7,8
73			C	Rabbit		I			8
74	d-Lysergic acid diethylamide	Acetylcholine	C	Guinea pig			0.07	I	19
75		Histamine	C	Cat		I	0.005-0.03	I	1,4
76			C	Guinea pig		I	<0.05	I	1,19
77		5-Hydroxytryptamine	C	Guinea pig		A	0.005-0.4	A	1,5,6,19
78		Methacholine	C	Guinea pig			0.02	(A)	19
79		Methyl-furmethide	C	Guinea pig			<0.08	I	19
80		Nicotine	C	Guinea pig			<0.08	I	19

/1/ Contains ergocornine, plus small amounts of ergokryptine and ergocristine.

Contributor: Hawkins, D. F.

References: [1] Konzett, H., Brit. J. Pharm. 11:289, 1956. [2] Curry, J. J., Fuchs, J. E., and Leard, S. E., J. Clin. Invest. 29:439, 1950. [3] Hawkins, D. F., and Paton, W. D., unpublished, 1957. [4] Gaddum, J. H., Hebb, C. O., Silver, A., and Swan, A. A., Quart. J. Exp. Physiol., Lond. 38:255, 1953. [5] Bhattacharya, B. K., Arch. internat. pharm. dyn., Par. 103:357, 1955. [6] Herxheimer, H., J. Physiol., Lond. 128:435, 1955. [7] Swanson, E. E., J. Pharm. Exp. Ther. 36:541, 1929. [8] Swanson, E. E., and Webster, R. K., ibid 38:327, 1930. [9] Melville, K. I., Arch. internat. pharm. dyn., Par. 58:129, 1938. [10] Warnant, H., ibid 37:61, 1930. [11] Loew, E. R., Kaiser, M. E., and Moore, V., J. Pharm. Exp. Ther. 86:1, 1946. [12] Hebb, C. O., J. Physiol., Lond. 96:29P, 1939. [13] Hebb, C. O., ibid 99:57, 1940. [14] Januschke, H., and Pollak, L., Arch. exp. Path. 66:205, 1911. [15] Jackson, D. E., J. Pharm. Exp. Ther. 4:59, 1912. [16] Daly, I. de B., Quart. J. Exp. Physiol., Lond. 28:357, 1938. [17] Hawkins, D. F. (thesis), London, 1952. [18] Villaret, M., Justin-Besançon, L., and Vexenat, G., C. rend. Soc. biol. 100:806, 1929. [19] Herxheimer, H., Arch. internat. pharm. dyn., Par. 106:371, 1956.

Part V: 2-HALOETHYLAMINES

Drugs are listed alphabetically. C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug: Compound	Active Drug: Effect	Species	Local: µg/ml	Local: Action	Systemic: mg/kg	Systemic: Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	N-[2-(2-Biphenylyloxy)-ethyl]-N-(2-chloroethyl)-allylamine	Histamine	C	Guinea pig			12.5	I	1
2	N-[2-(2-Biphenylyloxy)-ethyl]-N-(2-chloroethyl)-amylamine	Histamine	C	Guinea pig			12.5	I	1
3	N-[2-(2-Biphenylyloxy)-ethyl]-N-(2-chloroethyl)-butylamine	Histamine	C	Guinea pig			25.0	I	1

Part V: 2-HALOETHYLAMINES (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, 1 = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug: Compound	Active Drug: Effect	Species	Antagonist or Potentiator Effect: Local: µg/ml	Local: Action	Systemic: mg/kg	Systemic: Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
4	N-[2-(2-Biphenylyloxy)-ethyl]-N-(2-chloroethyl)-ethylamine	Histamine	C	Guinea pig			6.0	A	1
5	N-[2-(2-Biphenylyloxy)-ethyl]-N-(2-chloroethyl)-hexylamine	Histamine	C	Guinea pig			25.0	1	1
6	N-[2-(2-Biphenylyloxy)-ethyl]-N-(2-chloroethyl)-isopropylamine	Histamine	C	Guinea pig			12.5	I	1
7	N-[2-(2-Biphenylyloxy)-ethyl]-N-(2-chloroethyl)-methylamine	Histamine	C	Guinea pig			1.5	A	1
8	N-[2-(2-Biphenylyloxy)-ethyl]-N-(2-chloroethyl)-n-propylamine	Histamine	C	Guinea pig			12.5	A	1
9	N-[2-(2-Biphenylyloxy)-ethyl]-N-(2-chloropropyl)-ethylamine	Histamine	C	Guinea pig			12.5	A	1
10	4-Chloro-N-(2-chloroethyl)-N-ethyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			12.5	1	2
11	N-(2-Chloroethyl)-N-allyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			3.0	A	2
12	N-(2-Chloroethyl)-N-n-amyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			12.5	I	2
13	N-(2-Chloroethyl)-N-n-butyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			12.5	A	2
14	N-(2-Chloroethyl)-N-sec.-butyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			12.5	A	2
15	N-(2-Chloroethyl)-N-ethyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			0.025-0.08	A	2,3
16	N-(2-Chloroethyl)-N-n-hexyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			25.0	I	2
17	N-(2-Chloroethyl)-N-isobutyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			12.5	I	2
18	N-(2-Chloroethyl)-N-isopropyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			3.0	A	2
19	N-(2-Chloroethyl)-N-(2-methoxyethyl)-1-naphthalenemethylamine	Histamine	C	Guinea pig			1.5	A	2
20	N-(2-Chloroethyl)-N-methyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			0.05-0.20	A	2,3
21	N-(2-Chloroethyl)-N-n-propyl-1-naphthalenemethylamine	Histamine	C	Guinea pig			1.0	A	2
22	N-[2-(2'-Cyclohexylphenoxy)-ethyl]-N-(2-chloroethyl)-ethylamine	Histamine	C	Guinea pig			25.0	I	1
23	N, N-Dibenzyl-2-chloroethylamine (Dibenamine)	Epinephrine	D	Guinea pig	1000	P			4
24		5-Hydroxytryptamine	C	Guinea pig		A			5
25		Norepinephrine	D	Guinea pig	1000	1			4

Part V: 2-HALOETHYLAMINES Concluded)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug		Species	Antagonist or Potentiator Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/kg	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
26	N, N-Di-(2-chloroethyl)-1-naphthalenemethylamine	Histamine	C	Guinea pig			25.0	A	2
27	N-Ethyl-N-(1-naphthylmethyl)-2-bromoethylamine	Histamine	C	Guinea pig			0.03-0.10	A	2,3
28	N-Ethyl-N-(2-naphthylmethyl)-2-bromoethylamine	Histamine	C	Guinea pig			1.5	A	3
29	N-Ethyl-N-(2-naphthylmethyl)-2-chloroethylamine	Histamine	C	Guinea pig			3.6		3
30	N-Ethyl-N-(1-naphthylmethyl)-2-fluoroethylamine	Histamine	C	Guinea pig				(I)	3
31	N-Ethyl-N-(2-naphthylmethyl)-2-fluoroethylamine	Histamine	C	Guinea pig			20.0	A	3
32	N-Ethyl-N-(1-naphthylmethyl)-2-iodoethylamine	Histamine	C	Guinea pig			0.10	A	3
33	N-Ethyl-N-(2-naphthylmethyl)-2-iodoethylamine	Histamine	C	Guinea pig			1.9	A	3
34	N-Methyl-N-(1-naphthylmethyl)-2-bromoethylamine	Histamine	C	Guinea pig			0.11	A	3
35	N-Methyl-N-(2-naphthylmethyl)-2-bromoethylamine	Histamine	C	Guinea pig			2.1	A	3
36	N-Methyl-N-(2-naphthylmethyl)-2-chloroethylamine	Histamine	C	Guinea pig			4.4	A	3
37	N-Methyl-N-(1-naphthylmethyl)-2-fluoroethylamine	Histamine	C	Guinea pig				(I)	3
38	N-Methyl-N-(2-naphthylmethyl)-2-fluoroethylamine	Histamine	C	Guinea pig			25.0	A	3
39	N-Methyl-N-(1-naphthylmethyl)-2-iodoethylamine	Histamine	C	Guinea pig			0.14	A	3
40	N-Methyl-N-(2-naphthylmethyl)-2-iodoethylamine	Histamine	C	Guinea pig			2.4	A	3
41	N-Phenyl-N-(1-naphthylmethyl)-2-bromoethylamine	Histamine	C	Guinea pig			9.0	A	3
42	N-Phenyl-N-(1-naphthylmethyl)-2-chloroethylamine	Histamine	C	Guinea pig			9.3	A	3
43	N-Phenyl-N-(1-naphthylmethyl)-2-iodoethylamine	Histamine	C	Guinea pig			8.5	A	3

Contributor: Hawkins, D. F.

References: [1] Loew, E. R., and Micetich, A., J. Pharm. Exp. Ther. 95:448, 1949. [2] Loew, E. R., and Micetich, A., ibid 94:339, 1948. [3] Graham, J. D., and Lewis, G. P., Brit. J. Pharm. 8:54, 1953. [4] Hawkins, D. F., and Paton, W. D., unpublished, 1957. [5] Bhattacharya, B. K., Arch. internat. pharm. dyn., Par. 103:357, 1955.

Part VI: TRIAZINES

Drugs are listed alphabetically. C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug). Parentheses in Column H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist (Synonym)	Active Drug		Species	Antagonist Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	2-(p-Aminophenyl)-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			50	(A)	1
2	2-Anilino-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			100	(I)	1

Part VI: TRIAZINES (Concluded)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug). Parentheses in Column H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist (Synonym)	Active Drug		Species	Antagonist Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
3	2-Benzyloxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			25.0	I	1
4	2-Butoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			25.0	A	1
5	2-sec.-Butoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			12.5-25.0	A	1
6	2-(o-Carboxyphenyl-amino)-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			100	(I)	1
7	2-Cyclohexoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			12.5-25.0	A	1
8	2-(β-Dimethylamino-ethoxy)-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			25.0	(A)	1
9	2-Ethoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			25-50	A	1
10	2-(β-Ethoxy-ethoxy)-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			50.0	A	1
11	2-Heptoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			25.0	I	1
12	2-Hexoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			12.5-25.0	A	1
13	2-(p-Hydroxyphenyl-amino)-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			100	(I)	1
14	2-Isobutoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			12.5-25.0	A	1
15	2-Isopropoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			12.5-25.0	A	1
16	2-Methoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			50.0	A	1
17	2-(p-Methylphenyl-amino)-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			100	(I)	1
18	2-(β-Morpholino-ethoxy)-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			100.0	(A)	1
19	2-Nonoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			25.0	I	1
20	2-Octoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			25.0	I	1
21	2-Pentoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			25.0	A	1
22	2-Phenoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			50.0	A	1
23	2-Propoxy-4, 6-diamino-s-triazine	Histamine	C	Guinea pig			12.5-25.0	A	1,2
24		Methacholine	C	Guinea pig			15.0	A	2
25	2, 4, 6-Triamino-s-triazine	Histamine	C	Guinea pig			100	(I)	1

Contributor: Hawkins, D. F.

References: [1] Loew, E. R., Kaiser, M. E., and Anderson, M., J. Pharm. Exp. Ther. 86:7, 1946. [2] Chen, G., and Ensor, C. R., J. Laborat. Clin. M. 34:1010, 1949.

Part VII: ESTERS

Drugs are listed alphabetically. C = constricts, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug). Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist (Synonym)	Active Drug		Species	Antagonist Effect				Reference
					Local		Systemic		
		Compound	Effect		μg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Diphenylacetic Esters								
1	Allylmethylaminoethyl diphenyl-(β-dimethyl-aminoethoxy)-acetate (Ro 3-0275)	Histamine	C	Guinea pig		I			1
2	1-Azabicyclo-[3,3,1]-nonyl 4-diphenylacetate (Ro 2-3493)	Methacholine	C	Guinea pig			0.06	A	2
3	1-Azabicyclo-[3,2,1]-octyl 6-diphenyl-acetate (Ro 2-3244)	Methacholine	C	Guinea pig			5.0	A	2
4	1-Azabicyclo-[3,2,1]-octyl 6-diphenylacetate methobromide (Ro 2-3951)	Methacholine	C	Guinea pig			1.0	A	2
5	Diallylaminoethyl diphenyl-(β-dimethylaminoethoxy)-acetate (Ro 3-0276)	Histamine	C	Guinea pig		A			1
6	Diethylaminoethyl diphenyl-(β-dimethyl-aminoethoxy)-acetate (Ro 3-0131)	Histamine	C	Guinea pig		A			1
7	Diethylaminoethyl diphenylhydroxythio-acetate (Ro 3-0226)	Acetylcholine	C	Guinea pig	0.008-0.02	A			3
8	Diethylaminoethyl diphenyl-(isopropyl-methylaminoethoxy)-acetate (Ro 3-0289)	Histamine	C	Guinea pig		A			1
9	Diethylaminoethyl diphenyl-(β-morpholinoethoxy)-acetate (Ro 3-0257)	Histamine	C	Guinea pig		I			1
10	β-Diethylaminoisopropyl diphenyl-(β-dimethyl-aminoethoxy)-acetate (Ro 3-0281)	Histamine	C	Guinea pig		A			1
11	β-Dimethylaminoethyl diphenylacetate (Trasentin)	Acetylcholine	C	Guinea pig	8.0	A			4,5
12		Histamine	C	Guinea pig	>10.0	A	50	I	4-7
13	Dimethylaminoethyl diphenyl-(β-dimethyl-aminoethoxy)-acetate (Ro 3-0190)	Histamine	C	Guinea pig		A			1
14	β-Isopropylmethyl-aminoethyl diphenyl-(β-dimethylaminoethoxy)-acetate (Ro 3-0282)	Histamine	C	Guinea pig		A			1
15	2-Methyl-1-azabicyclo-[3,3,1]-nonyl 4-diphenyl-acetate (Ro 2-3521)	Methacholine	C	Guinea pig			1.0	A	2
16	β-Morpholinoethyl diphenyl-(β-dimethyl-aminoethoxy)-acetate (Ro 3-0280)	Histamine	C	Guinea pig		A			1
17	β-Morpholinoethyl diphenyl-(β'-morpholinoethoxy)-acetate (Ro 3-0265)	Histamine	C	Guinea pig		I			1
18	Piperidinoethyl diphenyl-acetamide (Hō 9980)	Acetylcholine	C	Guinea pig			0.25	A	9
19		Physostigmine	C	Guinea pig			0.25	A	9
20		Pilocarpine	C	Guinea pig			0.25	A	9

Part VII: ESTERS (Continued)

C = constricts, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug). Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist (Synonym)	Active Drug: Compound	Active Drug: Effect	Species	Antagonist Effect: Local: µg/ml	Antagonist Effect: Local: Action	Antagonist Effect: Systemic: mg/kg	Antagonist Effect: Systemic: Action	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Diphenylacetic Esters (concluded)								
21	Piperidinoethyl diphenyl-(β-dimethylaminoethoxy)-acetate (Ro 3-0277)	Histamine	C	Guinea pig		A			1
22	Quinuclidinyl 3-α-allyl-diphenylacetate (Ro 2-3802)	Methacholine	C	Guinea pig			1.0	A	2
23	dl-Quinuclidinyl 3-diphenylacetate (Ro 2-3202)	Methacholine	C	Guinea pig			0.1	A	2
24	d-Quinuclidinyl 3-diphenylacetate (Ro 2-4040)	Methacholine	C	Guinea pig				(I)	2
25	l-Quinuclidinyl 3-diphenylacetate (Ro 2-4030)	Methacholine	C	Guinea pig			0.05	A	2
26	Quinuclidinyl 3-diphenyl-acetate methobromide (Ro 2-3203)	Methacholine	C	Guinea pig			0.10	A	2
	Miscellaneous Esters								
27	1-Azabicyclo-[3,2,1]-octyl 6-fluorene-9-carboxylate (Ro 2-3245)	Methacholine	C	Guinea pig			1.0	A	2
28	β-Diethylaminoethyl 9,10-	Acetylcholine	C	Dog			1.0	(A)	10
29	dihydroanthracene-9-	Histamine	C	Dog			1.0	A	10
30	carboxylate		C	Guinea pig		A			11
31	β-Diethylaminoethyl	Acetylcholine	C	Dog			1.0	(A)	10
32	fluorene-9-carboxylate	Histamine	C	Dog			1.0	(I)	10
33	(Pavatrine)		C	Guinea pig			<50	I	7
34	3-(β-Diethylaminoethyl)-3-phenyl-2-benzofuranone (Amethone; AP 43)	Histamine	C	Guinea pig		(A)			12
35	2-Diethylaminoethyl	Acetylcholine	C	Guinea pig		A			5
36	1-phenylcyclopentane-1-carboxylate (Caramiphen; Parpanit)	Histamine	C	Guinea pig		A			5
37	Ethyl 1-methyl-4-phenyl-	Histamine	C	Guinea pig	0.1-5.0	A	0.1-25.0	A	6, 13-18
38	piperidine-4-carboxylate (Pethidine; Demerol; Dolantin; Isonipecaine; Meperidine)	Methacholine	C	Guinea pig		A	64.0	A	14
39	N-Ethyl-piperidyl 3-	Acetylcholine	C	Guinea pig	0.05	A			8
40	benzilate methobromide	Histamine	C	Guinea pig	10.0	I			8
41	(JB 323)	Methacholine	C	Guinea pig			0.5-3.0	A	8
42	β-Piperidinoethyl methyl-p-xenylacetate (WIN 5786)	Histamine	C	Guinea pig		A	0.5-2.0	A	19
43	Quinuclidinyl 3-benzilate (Ro 2-3308)	Methacholine	C	Guinea pig			0.025	A	2
44	Quinuclidinyl 3-benzilate methobromide (Ro 2-3773)	Methacholine	C	Guinea pig			0.20	A	2

Contributor: Hawkins, D. F.

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Part VIII: MISCELLANEOUS COMPOUNDS

Drugs are listed alphabetically. C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug		Species	Antagonist or Potentiator Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	6-Allyl-6, 7-dihydro-5H-dibenz (c, e) azepine (Ro 2-3248)	Epinephrine	D	Guinea pig	10.0	I			1
2	Alstonine	Epinephrine	D	Dog				I	2
3	Anagyrine	Nicotine	D	Guinea pig	2.0	A			3
4	d-Arginine	Acetylcholine	C	Guinea pig			300-1000	(P)	4
5		Histamine	C	Guinea pig			300-1000	I	4
6	Ascorbic acid	Epinephrine	D	Man	30-500	(P)			5, 6
7			D	Guinea pig		I			3
8		Nicotine	D	Guinea pig		(I)			3
9	Citrinin	Acetylcholine	C	Guinea pig		I			7
10		Epinephrine	D	Guinea pig		I			7
11		Histamine	C	Guinea pig		I			7
12	Chloroguanide (Paludrine)	Histamine	C	Guinea pig			5.0	P	8
13	Cocaine	Arecoline	C	Dog			7-14	I	9
14		Diethylmorphine	C	Cat		A			10
15			C	Dog		A	7-14	(A)	9,10
16		Ephedrine	D	Cat		A			10
17			D	Dog		A	7-14	A	9,10
18			D	Rabbit		A			10
19		ψ-Ephedrine	D	Cat		A			10
20			D	Dog		A	7-14	A	9,10
21			D	Rabbit		A			10
22		Epinephrine	D	Cat		I			10
23			D	Dog		I	7-14	P	9,10
24			D	Guinea pig	100	P			3
25			D	Rabbit		I			10
26		Histamine	C	Cat		I			10
27			C	Dog		I	7-14	(A)	9,10
28			C	Rabbit		I			10
29		5-Hydroxytryptamine	C	Cat		A			11
30		Morphine	C	Cat		A			10
31			C	Dog		A	7-14	A	9,10
32		Nicotine	C	Cat	1.0	A			3
33			D	Guinea pig	0.05-1.0	A			3
34		Peptone	C	Guinea pig	1000	A			12
35		Physostigmine	C	Dog			7-14	I	9
36		Pilocarpine	C	Dog			7-14	I	9
37	Coniine	Nicotine	D	Guinea pig	0.5	A			3
38	Cortisone	Histamine	C	Guinea pig	100	I			13
39	Cytisine	Nicotine	D	Guinea pig	5	A			3
40	Emetine	Histamine	C	Cat			1-5	(A)	14
41			C	Guinea pig	10,000-40,000	A			14
42	n-Heptyl isothiourea	Histamine	C	Guinea pig			5-10	A	15

Part VIII: MISCELLANEOUS COMPOUNDS (Continued)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug		Species	Antagonist or Potentiator Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
43	Hexamethonium	Acetylcholine	C	Cat	1.0	I			3
44			C	Guinea pig	<500	I	1-20	A	3,16
45			C	Monkey	10.0	I			3
46		Choline	C	Guinea pig	<500	(I)			3
47		Coniine	C	Guinea pig	10	I			3
48		Epinephrine	D	Guinea pig	<400	I			3
49		Histamine	C	Guinea pig	50-100	P	1-10	A	3,16
50		5-Hydroxytryptamine	C	Guinea pig			20	A	16
51		Lobeline	C	Guinea pig	10-40	I			3
52			D	Guinea pig	10	I			3
53		Methacholine	C	Guinea pig			1-20	A	16
54		Methyl-furmethide	C	Guinea pig			5-10	A	16
55		Nicotine	C	Cat	1.0	A			3
56			D	Cat	10	A			3
57			C	Guinea pig			0.1-20.0	A	16
58			D	Guinea pig	0.1-1.0	A			3
59		Norepinephrine	D	Guinea pig	<400	I			3
60		Pilocarpine	C	Guinea pig	<10	I			3
61		Tetramethyl-ammonium	C	Guinea pig	80-400	I			3
62	n-Hexyl-isothiourea	Acetylcholine	C	Rabbit		(A, P)			17
63		Histamine	C	Guinea pig			5-10	A	15
64	l-Histidine	Acetylcholine	C	Guinea pig			300	(P)	4
65		Histamine	C	Guinea pig			300-1000	I	4
66	N-(2-Hydroxyethyl)-N-ethyl-1-naphthalene-methylamine	Histamine	C	Guinea pig			25.0	I	18
67	Lobeline	Epinephrine	D	Guinea pig		I			3
68		Nicotine	D	Guinea pig	1.0	A			3
69		Norepinephrine	D	Guinea pig		I			3
70	Magnesium	Barium	C	Cat		A			19
71	4-Methylesculetin disulphuric acid (IDRO-P_2; Vitamin P)	Epinephrine	D	Man	20	P			6
72	2-Methyl-4-amino-5-methylamino-pyrimidine (β_1-Pyrimidine; Grewe diamine)	Histamine	C	Guinea pig	0.01-100	P			3,20,21
73		β-Pyridylethylamine	C	Guinea pig		I			21
74	Methyl isothiourea	Acetylcholine	C	Rabbit		P			17
75		Histamine	C	Guinea pig			2-5	(P)	15
76	Pentamidine isethionate	Acetylcholine	C	Guinea pig			25	P	22
77		Histamine	C	Guinea pig			25	P	22
78	Pentobarbital sodium	Histamine	C	Guinea pig			20	(I)	23
79	Phentolamine (Regitine; 7337)	Epinephrine	D	Guinea pig		I			3
80		Nicotine	D	Guinea pig	2.0	A			3
81		Norepinephrine	D	Guinea pig		I			3
82		5-Hydroxytryptamine	C	Guinea pig		A			24
83	Piperoxan (933F)	Acetylcholine	C	Dog			10	I	25
84	Prosympal (883F)	Epinephrine	D	Guinea pig	<100	I			3
85		Nicotine	D	Guinea pig	1-2	A			3
86		Norepinephrine	D	Guinea pig	<100	I			3
87	Quinidine	Histamine	C	Guinea pig			5	A	26
88	Rutin (Quercetin rhamnoglucoside; Vitamin P)	Histamine	C	Guinea pig		I			27
89	Semicarbazide	Histamine	C	Guinea pig	0.01-1.0	P			20,21
90			C	Guinea pig	100	A			20,21
91		β-Pyridylethylamine	C	Guinea pig	1.0	I			20,21

Part VIII: MISCELLANEOUS COMPOUNDS (Concluded)

C = constricts, D = dilates, A = antagonizes active drug effect, I = inactive (i.e., without influence on effect of active drug), P = potentiates active drug effect. Parentheses in Columns F and H indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist or Potentiator (Synonym)	Active Drug		Species	Antagonist or Potentiator Effect				Reference
		Compound	Effect		Local		Systemic		
					µg/ml	Action	mg/kg	Action	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
92	Sparteine	Nicotine	D	Guinea pig	0.5	A			3
93	Suramin	Acetylcholine	C	Guinea pig			250	A	22
94		Histamine	C	Guinea pig			250	A	22
95		Pentamidine	C	Guinea pig			250	A	22
96	Tetramethylene di-iso-thiourea	Histamine	C	Guinea pig			5	(A)	15
97	Tolazoline (Priscol)	Epinephrine	D	Guinea pig	10-100	P			3
98		Nicotine	D	Guinea pig	10-20	A			3
99		Norepinephrine	D	Guinea pig	100	P			3
100	Urethane	Barium	C	Rabbit	5,000-10,000	A			28
101			C	Sheep	5,000-10,000	A			28
102		Epinephrine	D	Rabbit	5,000-10,000	I			28
103			D	Sheep	5,000-10,000	I			28
104		Pilocarpine	C	Rabbit	5,000-10,000	A			28
105			C	Sheep	5,000-10,000	A			28
106		Sodium nitrite	D	Rabbit	5,000-10,000	A			28
107			D	Sheep	5,000-10,000	A			28
108	Yohimbine	5-Hydroxytryptamine	C	Guinea pig		I			29

Contributor: Hawkins, D. F.

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136. pA_x VALUES FOR ANTAGONISTS OF DRUGS ACTING ON THE BRONCHI

Values are the negative logarithm of the molar concentration of antagonist required to reduce the response to an "x-fold" dose of active drug to that produced by a single dose of active drug in the absence of antagonist [1]. Parentheses indicate action is irregular and the original literature should be consulted. C = constricts, D = dilates.

	Antagonist	Active Drug	Effect	Species	Antagonist Contact Time				Reference
					2 min	10-15 min	20-30 min	30 min	
					pA_2			pA_{10}	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Atropine	Acetylcholine	C	Guinea Pig			8.0		2
2			C	Guinea pig			8.8	7.6	3
3		Histamine	C	Guinea pig			5.9	5.0	3
4	Dihydroergotamine	Epinephrine	D	Guinea pig			6.3		4
5		Isoproterenol	D	Guinea pig			6.3		4
6		Nicotine	D	Guinea pig			6.4		4
7		Norepinephrine	D	Guinea pig			(4.8)		4
8	Diphenhydramine	Histamine	C	Guinea pig		7.8	7.8	6.9	3
9		β-Pyridylethylamine	C	Guinea pig		8.3			3
10	Ergotamine	Epinephrine	D	Guinea pig			6.0		4
11		Isoproterenol	D	Guinea pig			6.1		4
12		Nicotine	D	Guinea pig			5.8		4
13		Norepinephrine	D	Guinea pig			(4.9)		4
14	Meperidine (Pethidine)	Histamine	C	Guinea pig			6.2	5.1	3
15	Pyrilamine (Mepyramine)	Histamine	C	Man	8.3	8.8	9.3		6
16			C	Guinea pig			8.7		2
17			C	Guinea pig	7.6	8.8	9.0		5
18			C	Guinea pig		9.1	9.4	8.4	3
19		β-Pyridylethylamine	C	Guinea pig		9.5			3

Contributor: Hawkins, D. F.

References: [1] Schild, H. O., Brit. J. Pharm. 2:189, 1947. [2] Parkes, M. W., personal communication, 1949. [3] Arunlakshana, O. (thesis), London, 1953. [4] Hawkins, D. F., and Paton, W. D., unpublished, 1957. [5] Hawkins, D. F. (thesis), London, 1952. [6] Hawkins, D. F. and Schild, H. O., Brit. J. Pharm. 6:682, 1951.

137. AEROSOLS, GASES, AND VAPORS ACTING ON THE BRONCHI

The classification employed is functional, with the drugs listed alphabetically within each Part. Inclusion of trade names is for informative purposes only and in no way implies endorsement by The National Academy of Sciences-The National Research Council. For all effects included in this table, there is reasonable evidence the drug in fact acted on the bronchial musculature. Where there was evidence that an effect was mediated by the respiratory center or adrenal glands, it was excluded. Similarly, results obtained in protecting guinea pigs against lethal doses of histamine were excluded, unless there was evidence of the relief of the bronchospasm. Drug actions influencing anaphylactic or asthmatic bronchospasm, or other pathological states, were also excluded. Concentrations for aerosols, unless otherwise specified, are mg/ml of the solution from which the aerosol was formed. Parentheses in Columns E (Part I) and D (Parts II and III) indicate action is slight, irregular, or doubtful, and the original literature should be consulted. C = constricts, D= dilates, I = inactive.

Part I: DIRECT ACTION

	Compound (Synonym)	Species	Mode of Administration	Concentration[1]	Effect	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Acetylcholine	Guinea pig	Aerosol	1-30	C	1-8
2	p-Aminobenzoic acid	Man	Aerosol	50-100	I	9
3	Aminophylline (Theophylline-ethylenediamine)	Man	Aerosol	250	(I)	10
4	Amyl nitrite	Cat	Vapor		D	11,12
5	Antazoline (Antistine)	Man	Aerosol	50	I	13
6	Antergan (Lergitin)	Man	Aerosol	20	C	13
7	Bromine	Cat	Vapor		C	12,14,15
8		Dog	Vapor		C	16
9	Calcium chloride	Man	Aerosol	200	D	13
10	Carbachol (Doryl; Carbaminoylcholine)	Man	Aerosol	5	C	9,13,18
11		Dog	Aerosol	10	C	19
12		Guinea pig	Aerosol		C	1
13	Chlorine	Calf	Gas	55-500 mg/L	(C)	20
14		Calf	Gas	600-1250 mg/L	C	20
15		Pig	Gas	55-500 mg/L	(C)	20
16		Pig	Gas	600-1250 mg/L	C	20
17	Chloroform	Cat	Vapor	30 vol %	C	11,12
18	Dibenzylmethylamine (566)	Man	Aerosol	10	D	13,18
19	Ether	Cat	Vapor		(D)	14
20		Cat	Vapor	30 vol %	C	11
21		Dog	Vapor		D	21,22
22	Ethyl chloride	Cat	Vapor		I	11
23	Furmethide (Furtrethonium; Furfuryl-trimethylammonium iodide)	Guinea pig	Aerosol		C	23
24	Glycerol	Man	Aerosol		I	17
25	Histamine	Man	Aerosol	30-300	C	24,25
26		Dog	Aerosol	20	C	26
27		Guinea pig	Aerosol	0.2-10.0[2]	C	27-29
28		Guinea pig	Aerosol	1-40	C	2,3,5, 30-35
29	Hydrocyanic acid	Cat	Gas		D	14
30	5-Hydroxytryptamine (Serotonin)	Man	Aerosol	10	I	36
31		Guinea pig	Aerosol	10	C	3
32	Methacholine (Mecholyl; Amechol; Acetyl-β-	Man	Aerosol	25-100	C	24, 25
33	methyl choline)	Guinea pig	Aerosol	2.5-24.0	C	1,36-39
34	Methyl-furmethide (5-Methylfurfuryl-trimethyl-ammonium iodide)	Guinea pig	Aerosol	2.5	C	4
35	Nicotine	Guinea pig	Aerosol	40	C	4
36	Nikethamide (Coramine)	Man	Aerosol	200	I	13
37	Nitrous oxide	Cat	Gas	60 vol %	I	11
38	Papaverine	Guinea pig	Aerosol	10	I	35
39	Pentylenetetrazol (Cardiazol; Metrazol)	Man	Aerosol	100	I	13
40	Physostigmine	Guinea pig	Aerosol	1	C	6
41	Pilocarpine	Guinea pig	Aerosol	2	C	6
42	Polyvinyl pyrrolidene	Man	Aerosol	125	I	17
43	Potassium chloride	Man	Aerosol	100-200	C	13
44	Procaine (Novocaine)	Man	Aerosol	100	D	9
45	Pyrilamine (Mepyramine; Pyranisamine; Neoantergan)	Man	Aerosol	20	C	13

/1/ See Headnote. /2/ μg/L of vaporized aerosol.

Part I: DIRECT ACTION (Concluded)

	Compound (Synonym)	Species	Mode of Administration	Concentration[1]	Effect	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
46	Stramonium	Cat	Fumes		D	12
47	Theophylline	Man	Aerosol	100	D	9

/1/ See Headnote, Page 250.

Contributor: Hawkins, D. F.

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Part II: SYMPATHOMIMETIC AMINES

D = dilutes, I = inactive. Parentheses in Column D indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Compound (Synonym)	Species	Aerosol[1]	Effect	Reference
	(A)	(B)	(C)	(D)	(E)
1	Adrenalone (1-(3,4-Dihydroxyphenyl)-1-oxo-2-methylamino-ethane)	Man	20	(D)	1
2	1-(m-Aminophenyl)-2-amino-ethanol (WIN 5548)	Guinea pig	10	I	2
3	1-(m-Aminophenyl)-2-isopropylamino-ethanol (WIN 5503)	Guinea pig	10	I	2
4	N-n-Butyl-arterenol (1-(3,4-Dihydroxyphenyl)-2-butylamino-ethanol)	Guinea pig	0.02	D	3
5	N-Cyclopentyl-arterenol (1-(3,4-Dihydroxyphenyl)-2-cyclopentyl-amino-ethanol)	Guinea pig	0.03	D	3
6	dl-Epinephrine (dl-Adrenaline; Vaponephrin)	Man	22.5	D	4-7
7	l-Epinephrine (l-Adrenaline)	Man	1-20	D	4,5,7
8		Dog	0.1-1.0	D	8
9	1-(m-Hydroxyphenyl)-2-amino-ethanol (WIN 5501)	Guinea pig	10	I	2
10	Isoproterenol (N-isopropyl-arterenol; Aleudrine; Isoprenaline; Isuprel; Neo-epinine)	Man	2-10	D	1,4,5,7
11		Dog	10	D	9
12		Guinea pig	0.0005	D	3
13	Neosynephrine (1-(m-Hydroxyphenyl)-2-methylamino-ethanol)	Man	4-10	D	1,4,7
14		Guinea pig	4	D	2
15	Norsympatol (1-(p-Hydroxyphenyl-2-amino-ethanol)	Man	4-40	D	1
16	Orthoxine (1-(o-Methoxyphenyl)-2-methylamino-propane)	Guinea pig	100	D	10
17	β-Phenylethylamine	Man	2	(D)	1
18	1-Phenyl-2-methylamino-ethanol	Guinea pig	2	D	1
19	Synephrine (Sympatol; 1-(p-Hydroxyphenyl)-2-methylamino-ethanol)	Man	2-60	D	1
20	Tyramine (1-(p-Hydroxyphenyl)-2-amino-ethane	Man	2	D	1

/1/ See Headnote, Page 250.

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Part III: ANTAGONISTS

Parentheses in Column D indicate action is slight, irregular, or doubtful, and the original literature should be consulted.

	Antagonist (Synonym)	Species	Aerosol[1]	Effect	Reference
	(A)	(B)	(C)	(D)	(E)
1	Antazoline (Antistine)	Guinea pig	5-20	Antagonizes histamine.	1,2
2	Antergan (Lergitin)	Guinea pig	2.5	Antagonizes histamine.	3
3	Atropine	Guinea pig	10-30	Inactive against histamine.	4
4	Bellafoline (Belladonna alkaloids)	Man	0.5	Antagonizes methacholine.	5
5	Bromothen	Guinea pig	2.5-20	Antagonizes histamine.	1,2
6	Chlorcyclizine (Histantin; Perazil)	Guinea pig	20	(Antagonizes) histamine.	1
7	Chlorneoantergan	Guinea pig	2.5	Antagonizes histamine.	1
8	Chlorothen (Chloropyrilene; Tagathen)	Guinea pig	2.5	Antagonizes histamine.	1,6
9	Chlorprophenpyridamine (Chlor-Trimeton)	Guinea pig	2.5	Antagonizes histamine.	1
10	Cocaine	Guinea pig	2.5-5	Antagonizes acetylcholine.	7
11		Guinea pig	2.5-5	Antagonizes histamine.	7
12		Guinea pig	2.5-5	Antagonizes 5-hydroxytryptamine.	7
13		Guinea pig	2.5-5	Antagonizes methacholine.	7
14		Guinea pig	2.5-5	Antagonizes nicotine.	7
15		Guinea pig	2.5-5	Inactive against methyl-furmethide.	7
16	Cyclizine (Marezine)	Guinea pig		(Antagonizes) histamine.	1
17	2-Dimethylaminoethoxy-4-chloro-diphenylmethane (01780)	Guinea pig		(Antagonizes) histamine.	1
18	2-Dimethylaminoethoxy-diphenyl-methane (C 5581 H)	Guinea pig	2.5-20	Antagonizes histamine.	1,2
19	N-Dimethylaminoethyl-phenothiazine (RP 3015)	Guinea pig	20	Antagonizes histamine.	1,2
20	Diphenhydramine (Benadryl)	Man	14	Antagonizes histamine.	8
21		Guinea pig	2.5-20	Antagonizes histamine.	1,2
22	Doxylamine (Decapryn)	Guinea pig	2.5-20	Antagonizes histamine.	1,2
23	N-(4-Fluorobenzyl)-N-(2-pyridyl)-N',N'-dimethyl-ethylenediamine	Guinea pig	2.5	Antagonizes histamine.	1
24	Hetramine	Guinea pig		(Antagonizes) histamine.	1
25	Meperidine (Demerol; Dolantin; Pethidine)	Guinea pig	10	Antagonizes histamine.	4
26	Methapyrilene (Thenylene; Histadyl)	Guinea pig	2.5-20	Antagonizes histamine.	1,2
27	o-Methoxy-β-phenyl isopropyl-methyl-benzylamine (II-RBH-85)	Guinea pig		(Antagonizes) histamine.	1
28	Phenindamine (Thephorin)	Guinea pig	20	Antagonizes histamine.	1
29	N-Phenyl-N-ethyl-N',N'-diethyl-ethylene-diamine (1571 F)	Guinea pig	50	Antagonizes histamine.	3
30	N-Phenyl-N-ethyl-N',N'-dimethyl-ethylene-diamine (RP 2325)	Guinea pig	10	Antagonizes histamine.	3
31	Procaine (Novocaine)	Guinea pig	20	Inactive against histamine.	9
32	Prophenpyridamine (Inhiston; Tri-Meton)	Guinea pig	1-20	Antagonizes histamine.	1,10
33	Pyrilamine (Mepyramine; Pyranisamine; Neoantergan)	Guinea pig	2.5-20	Antagonizes histamine.	1,2
34	Pyrrolazote	Guinea pig	2.5-5	Antagonizes histamine.	1,2
35	Scopolamine	Man	0.6	Antagonizes methacholine.	5
36	N-2-Thiazolyl-N-(p-Methoxybenzyl)-N',N'-dimethyl-ethylenediamine (194 B)	Guinea pig	20	Antagonizes histamine.	1
37	Thonzylamine (Neohetramine)	Guinea pig	20	Antagonizes histamine.	1,2,11
38	Trasentin	Guinea pig	20	Inactive against histamine.	9
39	Tripelennamine (Pyribenzamine)	Man	20	Antagonizes histamine.	8
40		Man	15-20	(Antagonizes) methacholine.	8,12
41		Guinea pig	5-20	Antagonizes histamine.	1,2,9,11

/1/ See Headnote, Page 250.

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138. EFFECTS OF EXTERNAL IONIZING RADIATION ON THE RESPIRATORY SYSTEM: MAMMALS

Abbreviations and definitions: KV = kilovolt, a unit of electrical potential equal to 1000 volts; KVP = kilovolt peak, the crest value of the potential wave in kilovolts; mev = million electron volts; r = roentgen, the quantity of X- or gamma radiation such that the associated corpuscular emission per 0.001293 g of air produces, in air, ions carrying one electrostatic unit of electrical charge of either sign; rem = roentgen equivalent for man (or mammal), the absorbed dose equal to the dose in rads multiplied by the RBE; rad = rad unit, equivalent to 100 ergs/g energy absorption; RBE = relative biological effectiveness, i.e., the appropriate value of the biological effectiveness of the radiation in question relative to that of X-radiation with an average specific ionization of 100 ion pairs per micron of water, for the particular biological system and biological effect under consideration and for the condition under which the radiation is received; n = neutron, a nuclear particle of zero charge and mass number 1; mc = millicurie, the quantity of radionucleid disintegrating at the rate of 3.7×10^7 atoms per second.

	Animal (A)	Type of Radiation (B)	Exposure or Administration (C)	Dosage (D)	Accumulated Dosage or Exposure Time (E)	Effect[1] (F)	Initial Symptom Manifestation (G)	Reference (H)
1	Man	Mixed: X ray 80 KV equivalent r plus gamma	Entire body, single exposure (accident)	480 r		Dyspnea.	24 hr	1
						Respiration rapid and shallow.	15 da and at death (24th da)	
				110 r		Pulmonary edema.	Post mortem	
		X ray 80 KV equivalent r	Hands, single exposure (accident)	5,000-40,000 rem				
2		Mixed: X ray 80 KV equivalent r plus gamma	Entire body, single exposure (accident)	1930 r		Increased respiratory rate.	7th da	1
						Respiration shallow, rapid, slightly irregular.	9th da	
				114 r		Pulmonary consolidation.	Post mortem (9th da)	
		X ray 80 KV equivalent r	Hands, single exposure (accident)	3,000-30,000 rem				
3		X ray 180 KV	Thorax and adjacent areas	100-200 r	1600 r	Pneumonitis.	1 mo	2
4		X ray 200 KV	Thorax	150 r	5,600-10,500 r	No evidence of pulmonary reaction.		3
5		X ray 200 KV	Thorax	200 r, 3 times/wk	1600-6000 r	Pulmonary fibrosis and atelectasis.	2 mo	4
6		X ray 200 KV	Thorax	500-850 r/da	1600-5000 r	Pulmonary fibrosis.		5
7		X ray 200 KV	Thorax	750-800 r	1750 r	Pneumonitis, pulmonary fibrosis.	2 mo	6
8		X ray 200 KV	Thorax, repeated exposure (therapy)	750-800 r	7800 r	Pleuropneumonitis.	3 da-1 wk	7
9		X ray 200 KV	Thorax, repeated exposure (therapy)		18,000 r	Fibrosing pneumonitis.	9 yr	8
10		X ray 200 KV	Thorax		6300 r	Pneumonitis, pulmonary fibrosis.	4 mo	9

/1/ The lesions reported may not be primary radiation effects, but a secondary manifestation of response to inflammation or infection which may be intercurrent or result from radiation-induced changes of tissues other than lung.

Abbreviations and definitions: KV = kilovolt, a unit of electrical potential equal to 1000 volts; KVP = kilovolt peak, the crest value of the potential wave in kilovolts; mev = million electron volts; r = roentgen, the quantity of X- or gamma radiation such that the associated corpuscular emission per 0.001293 g of air produces, in air, ions carrying one electrostatic unit of electrical charge of either sign; rem = roentgen equivalent for man (or mammal), the absorbed dose equal to the dose in rads multiplied by the RBE; rad = rad unit, equivalent to 100 ergs/g energy absorption; RBE = relative biological effectiveness, i.e., the appropriate value of the biological effectiveness of the radiation in question relative to that of X-radiation with an average specific ionization of 100 ion pairs per micron of water, for the particular biological system and biological effect under consideration and for the condition under which the radiation is received; n = neutron, a nuclear particle of zero charge and mass number 1; mc = millicurie, the quantity of radionucleid disintegrating at the rate of 3.7×10^7 atoms per second.

	Animal	Type of Radiation	Exposure or Administration	Dosage	Accumulated Dosage or Exposure Time	Effect[1]	Initial Symptom Manifestation	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
11	Man (concluded)	X ray 230-250 KV	Neck and thorax		2450-3000 r	Pneumonitis.	1 wk	10
12		X ray 250 KV	Thorax, repeated exposure (therapy)		4500 r 52 da	Pulmonary fibrosis.		11
13		X ray 250-1000 KV	Thorax	100-200 r/da	1850-4000 r	Pneumonitis.	1 mo	12
14		X ray 250-1000 KV	Thorax	123-300 r/da	3,200-12,600 r	Pneumonitis.	2 da	13
						Fibrosis.	6 wk	
15		X ray 250-1000 KV	Thorax	500 r/da	3000-6000 r	Pneumonitis.	6 wk	14
16		X ray 1 mev	Oropharynx, repeated exposure (therapy)	500 r/da	4000-5000 r	Laryngeal edema with fibrosis, apical pulmonary fibrosis.	3-5 wk	15
17		X ray 1 mev	Lower left abdomen, repeated exposure (therapy)		5000 r 3 mo	Dyspnea, rapid respiration.	9 yr	16
18		X ray 2 mev	Thorax	200 r/da	3000-5000 r	Pneumonitis, fibrosis, pleural effusion.	2 mo	17
19		X ray	Thorax, repeated exposure (therapy)		800-1000 r Threshold: 600 r	Pleuropneumonitis.		18
20		X ray	Thorax, repeated exposure (therapy)		800-15,000 r	Pneumonitis.	1 da	19
21		X ray	Thorax, repeated exposure (therapy)	100-200 r/da	8240 r	Pulmonary fibrosis.		20
				200 r/da	4600 r	Pulmonary infiltration.		
22		X ray	Thorax, repeated exposure (therapy)		12,000 r	Pulmonary exudation, atelectasis, fibrosis.		21
23		X ray	Thorax, repeated exposure (therapy)	175-250 r/da	7 da	Pulmonary fibrosis.	1 mo	22
24		Radium (gamma)	Thorax and adjacent areas	1.0-1.5 mg		Pulmonary fibrosis.		2
25		$Cobalt^{60}$	Axillary, supraclavicular, parasternal; repeated exposure (therapy)		5000 r 15-25 da	Cough, dyspnea, pneumonitis, pulmonary fibrosis.		23

26		Atomic bomb detonation, Japan, 1945	Entire body, single exposure (military)	Lethal		Pulmonary emphysema, edema and focal atelectasis.	Terminal 1-2 wk	24
						Neutropenic pneumonia.	Terminal 3-6 wk	
27		Atomic bomb	Entire body, single exposure (military)	400-450 r, estimated (LD-50/60)		Pulmonary perivascular and pleural edema.	1-4 wk	25
28	Burro	Gamma Tantalum[182] Cobalt[60]	Entire body, single exposure	710 r (LD-50/30 = 780 r)		Respiration slow and shallow, dyspnea, pulmonary edema and hemorrhage.	Terminal 26.5 da average	26
29		Gamma Cobalt[60]	Entire body, repeated exposure	200 r/da	Until death, 5-16 da	Decreased respiratory quotient, O_2 consumption, CO_2 expiration.	1st da	27
30	Dog	X ray 130 KV	Abdomen, repeated exposure	1400-2800 r		Pulmonary edema.	Terminal 4-6 da	28
31		X ray 250 KV	Entire body, single exposure	10,000 r		Hyperventilation.	Immediate	29
32		X ray 200 KVP	Entire body, repeated exposure	12.5-50 r/da	880-1262 r	Respiration labored, diaphragmatic.	1-5 da before death	30
33		X ray 200 KVP	External	1200-4800 r		Early edema and congestion, petechial hemorrhage, and lymphangiectasia. Hypertrophy and anaplasia of alveolar lining cells. Anaplasia and stratification in bronchi and bronchioles. Hyaline membrane infrequent. Degeneration of elastica of alveoli, pleura, and vessels. Pleura relatively resistant.[2,3]	3 da-1 wk	31
34		X ray 2 mev	Entire body, single exposure	600 r (LD-100/30)		Inflammation of epiglottis, larynx, trachea, and bronchi; submucosal petechiae; subpleural petechiae and ecchymosis; congestion of alveolar capillaries and blood vessels; edema of alveolar walls.	Terminal	32
35	Guinea pig	Radium	Entire body, repeated exposure	0.11-8.8 r/da	Life span	Lung tumors.	Terminal	33
36	Hamster	X ray 2 mev	Entire body, single exposure	70,000 r		Normal respiration.	Immediate	34
				80,000 r		Rapid breathing.		
				100,000 r		Irregular breathing.		
37	Monkey	X ray 200 KV	Entire body, repeated exposure	100 r 35-da intervals	900 r	Pulmonary hemorrhage.		35
38		X ray 250 KV	Entire body, single exposure	400-800 r (LD-50/30 = 600 r)		Dyspnea.		36
39		Gamma Barium[140] Lanthanum[140]	Entire body, single exposure	1000 r/min	2500 r	Respiratory minute volume increased.		37
					10,000-30,000 r	Respiratory minute volume decreased.		

/1/ The lesions reported may not be primary radiation effects, but a secondary manifestation of response to inflammation or infection which may be intercurrent or result from radiation-induced changes of tissues other than lung. /2/ Pathological changes noted in irradiated experimental animals may occasionally be seen in unirradiated animals. /3/ Possible factors influencing severity of pneumonitis are species of animal, dose of radiation, fractionation and protraction, secondary infection.

Abbreviations and definitions: KV = kilovolt, a unit of electrical potential equal to 1000 volts; KVP = kilovolt peak, the crest value of the potential wave in kilovolts; mev = million electron volts; r = roentgen, the quantity of X- or gamma radiation such that the associated corpuscular emission per 0.001293 g of air produces, in air, ions carrying one electrostatic unit of electrical charge of either sign; rem = roentgen equivalent for man (or mammal), the absorbed dose equal to the dose in rads multiplied by the RBE; rad = rad unit, equivalent to 100 ergs/g energy absorption; RBE = relative biological effectiveness, i.e., the appropriate value of the biological effectiveness of the radiation in question relative to that of X-radiation with an average specific ionization of 100 ion pairs per micron of water, for the particular biological system and biological effect under consideration and for the condition under which the radiation is received; n = neutron, a nuclear particle of zero charge and mass number 1; mc = millicurie, the quantity of radionucleid disintegrating at the rate of 3.7×10^7 atoms per second.

	Animal	Type of Radiation	Exposure or Administration	Dosage	Accumulated Dosage or Exposure Time	Effect[1]	Initial Symptom Manifestation	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
40	Monkey (concluded)	Gamma Cobalt60	Entire body, single exposure	1000 r +		Respiratory rate increased.	100 min	38
				5,000-10,000 r		Tidal volume and respiratory minute volume increased. O_2 consumption rate depressed.		
41	Mouse	X ray	Entire body	400-799 r	500 r	Earlier evidence of pulmonary adenoma.	At 500 r	39
42		X ray and thermal neutrons with gamma	Entire body	16-512 n	512 X ray equivalents	Increased incidence of pulmonary adenomas developing late in life.		40
43		Radium	Entire body, repeated exposure	0.11-8.8 r/da	Life span	Lung tumors.	Terminal	33
44		Radium (gamma)	Entire body	0.11 r/da	88 r	Increased and/or earlier incidence of of tumors.	800 da	41
45		Radium (gamma)	Entire body	4.4 r/da	4000 r		480 da	42
46		Radium (gamma)	Entire body	8.8 r/da	2500 r		284 da	43
47	Rabbit	X ray 65 KVP 110 KVP 175 KVP	External	1700 r in 1 da to 12,000 r in 12 da		At least 75% incidence of pneumonitis, varying from minimal change at 1700 r dosage to severe pneumonia and fibrosis with frequent death at 12,000 r.		44
						Initial stage of 24-48 hr duration: Hyperemia, leucocytic infiltration, increased mucous secretion in bronchi.	Within 2 hr	
						Latent stage of 2-3 wk duration. Chief reaction stage, reaching maximum 1-2 mo after irradiation then slowly regressing: acute inflammation, peribronchitis, perivascular infiltration, bronchopneumonia. Degeneration of bronchial epithelium and lung stroma. Giant cell formation.	2-3 wk after irradiation	
						Regenerative stage, which may continue more than 6 mo after irradiation: connective tissue proliferation and	2-3 mo after irradiation	

						sclerotic processes. Frequently, calcification. Slight proliferation of bronchial epithelium. Degenerative changes also noted.		
48		X ray 200 KVP	Entire body, single exposure	800 r (LD-50/30)		Hydrothorax.	24 hr	45
						Pulmonary hemorrhage and edema.	6-12 da	
49		X ray 260 KVP	Entire body, single exposure	630 r		Accelerated respiration.	80-180 min	46
50		X ray 260 KVP	Head, single exposure	240 r/min	14,000 r	Decreased respiration.	30 min	47
51		X ray 160 KVP 200 KVP	External	300-5400 r		Early edema and congestion, petechial hemorrhage, and lymphangiectasia. Hypertrophy and anaplasia of alveolar lining cells. Anaplasia and stratification in bronchi and bronchioles. Hyaline membrane infrequent. Degeneration of elastica of alveoli, pleura, and vessels. Pleura relatively resistant.[3]	2 hr-5 mo	31
52		Radon	Probably external	1925-2800 mc hr			5-6 wk	
53		X ray	Head, single exposure	1000-4000 r		Dyspnea.	12 hr	48
54		X ray	Thorax, repeated exposure		6400-13,000 r	Degenerative changes in bronchial epithelium and lung stroma. Inflammatory processes in peribronchial, perivascular, and alveolar tissues.		20
55		X ray	Thorax, repeated exposure	Intensive		Pulmonary edema, congestion, fibrosis, atelectasis.		49
56		Radium	Entire body, repeated exposure	0.11-8.8 r/da	Life span	Lung tumors.	Terminal	33
57	Rat	X ray 200 KV	Entire body, single exposure	809-920 r	Lethal	Increased O_2 consumption.	24 hr	50
				648-972 r	Lethal	Increased O_2 consumption.	24 hr	
						Decreased O_2 consumption.	Terminal 9-10 da	
				648 r	Non-lethal	Increased O_2 consumption.	1-2 wk	
				54-432 r	Non-lethal	Increased O_2 consumption.	Transient	
58		X ray 220 KV	Entire body, single exposure	300-1000 r		Small decrease in basal O_2 consumption.	1-3 da	51
				800 r		Basal O_2 consumption increased.	4th da	
59		X ray 250 KV	Thorax, single exposure	3000 r		Pulmonary fibrosis.		52
60		X ray 160 KVP 200 KVP 1000 KVP	External	1200-3000 r		Early edema and congestion, petechial hemorrhage, and lymphangiectasia. Hypertrophy and anaplasia of alveolar lining cells. Anaplasia and stratification in bronchi and bronchioles. Hyaline membrane infrequent. Degeneration of elastica of alveoli, pleura, and vessels. Pleura relatively resistant.[3]	1 hr-12 wk	31

/1/ The lesions reported may not be primary radiation effects, but a secondary manifestation of response to inflammation or infection which may be intercurrent or result from radiation-induced changes of tissues other than lung. /3/ Possible factors influencing severity of pneumonitis are species of animal, dose of radiation, fractionation and protraction, secondary infection.

Abbreviations and definitions: KV = kilovolt, a unit of electrical potential equal to 1000 volts; KVP = kilovolt peak, the crest value of the potential wave in kilovolts; mev = million electron volts; r = roentgen, the quantity of X- or gamma radiation such that the associated corpuscular emission per 0.001293 g of air produces, in air, ions carrying one electrostatic unit of electrical charge of either sign; rem = roentgen equivalent for man (or mammal), the absorbed dose equal to the dose in rads multiplied by the RBE; rad = rad unit, equivalent to 100 ergs/g energy absorption; RBE = relative biological effectiveness, i.e., the appropriate value of the biological effectiveness of the radiation in question relative to that of X-radiation with an average specific ionization of 100 ion pairs per micron of water, for the particular biological system and biological effect under consideration and for the condition under which the radiation is received; n = neutron, a nuclear particle of zero charge and mass number 1; mc = millicurie, the quantity of radionucleid disintegrating at the rate of 3.7 x 10^7 atoms per second.

	Animal	Type of Radiation	Exposure or Administration	Dosage	Accumulated Dosage or Exposure Time	Effect[1]	Initial Symptom Manifestation	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
61	Rat (concluded)	X ray 250 KVP	External, single exposure on anesthetized animals	3000 r		Animals with complete atelectasis of irradiated lung: shift of mediastinum to collapsed side. Compensatory emphysema of non-irradiated lung. Proliferation, hypertrophy, and squamous metaplasia of bronchial and tracheal epithelium frequent. Inflammatory cell exudation and abscess formation. Peribronchial fibrosis. Thickening of blood vessel walls, perivascular fibrosis, and capillary obliteration. 100% incidence of pneumonitis, with high mortality usually caused by bilateral pneumonia. Animals with no collapse of irradiated lung: changes minimal or none at all.	10-60 da	53
62		X ray 250 KVP	Thorax, single exposure	3000 r		Atelectasis, pulmonary collapse, fibrosis.		54
63	Swine	X ray 200 KVP	External	12,300 r		Early edema and congestion, petechial hemorrhage, lymphangiectasia. Hypertrophy and anaplasia of alveolar lining cells. Anaplasia and stratification in bronchi and bronchioles. Hyaline membrane infrequent. Degeneration of elastica of alveoli pleura and vessels. Pleura relatively resistant.[3]	1 wk	31
64		X ray 1000 KVP	Entire body, single exposure	600 r		Pulmonary edema and hemorrhage.	Terminal	55
65		Bomb (Bikini)	Entire body, single exposure	20,000 r		Increased respiratory rate.	5 da	56
66		Atomic bomb source (gamma)	Entire body, single exposure	700 r		Increased respiratory rate. Atelectasis; constricted bronchioles, pulmonary edema, and hemorrhage.	Terminal (7th da)	57

/1/ The lesions reported may not be primary radiation effects, but a secondary manifestation of response to inflammation or infection which may be intercurrent or result from radiation-induced changes of tissues other than lung. /3/ Possible factors influencing severity of pneumonitis are species of animal, dose of radiation, fractionation and protraction, secondary infection.

Contributors: (a) Michaelson, S., and Ingram, M., (b) Chu, F. C., and Glicksman, A. S., (c) Stannard, J. N.

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139. EFFECTS OF INTERNAL RADIATION EMITTERS ON THE RESPIRATORY SYSTEM: MAMMALS

The tabulation below is a selection of studies in which there was either a clear-cut effect of the radiation or clearly no demonstrable effect, thereby making possible an approach to an estimate of effective doses. It is not the purpose of this compilation to imply that a true threshold exists, for more complex experiments would be required to demonstrate effects at lower levels. All experiments, except those involving implanted sources, represent radioactive material free to move about in the lung and subject to removal by pulmonary clearance mechanisms. Doses were usually calculated over the entire period of exposure, assuming an average effective half-life and exponential kinetics of loss. In some instances, these calculations may overestimate the dose needed to produce damage; however, this is not true generally because biological removal is moderately rapid compared with the periods of exposure. Abbreviations and definitions: rad = rad unit, equivalent to 100 ergs/g energy absorption; mc = millicurie, the quantity of radionucleid disintegrating at the rate of 3.7×10^7 atoms per second; µc = microcurie, 3.7×10^4 disintegrations per second; c/L = curies per liter; mc-hr/L = millicuries x hours per liter.

	Animal	Type of Radiation	Exposure or Administration	Dosage	Calculated Lung Dosage	Effect	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Man	Radium, radon and daughters (largely alpha)	Calculation of radiation dose to lung	1×10^{-11} c/L	Lung: 0.0042-0.0093 rad/wk (15-34 rad/70 yr) Bronchi: 0.07-0.10 rad/wk (229-344 rad/70 yr)	No measurable effect.	1

Abbreviations and definitions: rad = rad unit, equivalent to 100 ergs/g energy absorption; mc = millicurie, the quantity of radionucleid disintegrating at the rate of 3.7×10^7 atoms per second; μc = microcurie, 3.7×10^4 disintegrations per second; c/L = curies per liter; mc-hr/L = millicuries x hours per liter.

	Animal	Type of Radiation	Exposure or Administration	Dosage	Calculated Lung Dosage	Effect	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
2	Man (concluded)	Radium, radon and daughters (largely alpha)	Calculation for exposure of upper bronchial epithelium in a mine where lung cancer was reported	3×10^{-9} c/L	0.65 rad/wk (560 rad in 17 yr)	Lung cancer occurs, but not proven to be result of radon and daughters exposure.	2, 3
					3000 rem in 17 yr	No measurable effect on larger bronchi.	4
3		Radium, radon and daughters (mostly alpha)	Repeated inhalation in mine atmosphere for 3-yr period	60 rep radium equivalent		Dyspnea, pulmonary fibrosis.	5
4		Radium, radon and daughters (mostly alpha)	Industrial exposure by inhalation for 13-23 yr	50-75 mg		Lung carcinogenesis, but casual relationship not proven.	6
5		Thorium and daughters (largely alpha)	Calculation of lung dose in patients administered 75 ml thorotrast	0.01 rep/da	85 rad in 25 yr (240 rad in 70 yr)	50% self-absorption assumed. No measurable effect on lung; damage seen in other tissues.	7
6	Cat	Radon (mostly alpha)	Medulla oblongata, single exposure	43-83 μc		Immediate stimulation of respiratory center.	8
7	Mouse	Aqueous radon solution (largely alpha)	Injection	0.013-0.017 mc/g	570 rad to lung (285 rad to whole body)	Acute pathologic changes; lung damage not described in detail. LD-50 expected.	9
8		Radon free of daughters (alpha)	Inhalation	4.3 mc-hr/L	Approximately 280 rad	Increased cellularity of bronchial mucosa 5-7 mo after exposure	10
9		Plutonium^{239} (alpha)	Intratracheal injection	0.06 μc PuO_2 per animal	1,890-22,000 rad[1]	Squamous cell carcinomas seen in 3 out of 10 animals after 1 yr.	11
10		Ruthenium^{106} oxide particles (beta)	Intratracheal injection	0.45-3.0 μc per animal	110 rad for 0.45 μc; 710 rad for 3.0 μc	Lower dose produced increase in papillary adenoma. Higher dose produced one malignant tumor (not a squamous cell carcinoma).	11, 12
11		Carrier-free phosphorus^{32} (beta)	Subcutaneous injection	25-2000 μc	93 rad for 25 μc; approximately 1000 rad for 250 μc; approximately 7500 rad for 2000 μc	No change that could be ascribed to radiation. Doses of 250 and 2000 μc were acutely toxic, 25 μc were not.	13
12		Iodine^{131} (beta, gamma)	Subcutaneous injection	10-1000 μc	5,000-10,000 rad for more than 80 μc	Tracheal tumors. Dose to trachea difficult to estimate because of short range of the I^{131} beta.	14

13	Rat	$Polonium^{210}$ (alpha)	Intratracheal injection	5 μc/kg	2500 rad in approximately 60 da	Gross and microscopic pathology; squamous cell carcinoma in 2 out of 15 animals and papillary adenomas in 1 of 15 animals. Tumors seen in other organs.	15
14		$Polonium^{210}$ (alpha)	Single intravenous injection	1-10 μc/kg	1360 rad at 10 μc/kg	Microscopic evidence of generalized radiation damage. Kidney lesion is cause of death at 10 μc/kg.	16
15		$Polonium^{210}$ (alpha)	Single intravenous injection	0.9-35.0 μc/kg		Microscopic evidence of radiation damage; atelectasis. Effects in lung mild as compared to other tissues.	17
16		$Polonium^{210}$ (alpha)	Single intravenous injection	26-70 μc/kg		Pulmonary edema; calcification of trachea. Part of generalized radiation damage.	18
17		$Plutonium^{239}$ (alpha)	Intratracheal injection	0.5-31.0 μc per animal (7.5-500 μg)	2,400-67,000 rad	Some gross and microscopic pathology noted in all animals at all dosage levels.	19
18		$Plutonium^{239}$ (alpha)	Inhalation of Pu smoke	1.5-31.5 μc per animal	Up to 46,000 rad	Extensive damage. Increased cellularity of bronchiolar epithelium. Neoplastic type change (proliferation) in some instances.	20
19		$Cerium^{144}$-praseodymium^{144} oxide (beta, gamma)	Inhalation	3.2-200 μc per animal	Up to 33,000 rad	Acute effects; hemorrhage and consolidation. Much damage but not easily distinguished from pneumonia.	21
20		$Cerium^{144}$-praseodymium^{144} oxide (beta, gamma)	Inhalation	3.2-200 μc per animal	Up to 33,000 rad	Metaplastic changes indicated as occurring, but complete report not available.	22
21		$Cerium^{144}$ fluoride (beta, gamma)	Intratracheal injection	5-50 μc per animal LD-50 = 45 μc	2150-2200 rad 4750-6400 rad 7900-9950 rad 4,850-19,500 rad	1 out of 27 1 out of 23 7 out of 28 3 out of 15 } Incidence of squamous cell carcinoma.	23
22		$BaS^{35}O_4$ (beta)	Intratracheal injection	4.5 μc - 4.5 mc per animal	22,500 rad	Inflammation and cicatrization seen only at highest dose.	24
23		$BaS^{35}O_4$ (beta)	Repeated intratracheal injection	375 μc once a wk for 10 wk	12,000-20,000 rad	25% incidence (6 out of 24) of squamous cell metaplasia and carcinoma.	23
24		Radioactive thallium activated clay (beta)	Intratracheal injection		105 rad over a period of 16 months	No effect observed. Used as example of an insoluble substance. Dosimetry around a point source difficult.	23, 25
25		$Strontium^{90}$ beads (beta)	Implanted	77-1920 rad/da	78,000 rad/2/ 47,000 rad/2/	Squamous cell carcinoma Lymphosarcoma Lymphoma } 6 or 7 tumors associated with the bead.	23
26		$Ruthenium^{106}$-rhodium^{106} (beta)	Implanted	0.007-14.0 μc	70 rad/2/ 200,000 rad/2/	Metaplasia. Bronchogenic carcinoma.	26
27	Swine	$Cobalt^{60}$ beads (gamma)	Implanted for 2 wk	1.5 mc in bead	6250 rad at surface of bead	Fibroblastic response; alteration in elastica were minor.	27

/1/ 1890 rad if 30 da chosen as effective half-life in lung; 22,000 rad if 360 da chosen. /2/ Doses at 100 micra.

Contributors: (a) Stannard, J. N., (b) Michaelson, S., and Ingram, M.

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Part I: VOLUNTARY CONTROL

Section 1: Breathholding

Ranges in parentheses are estimate "c" of the 95% range (cf Introduction).

	Breathholding Time sec	Alveolar Air			
		Before		After	
		O_2, %	CO_2, %	O_2, %	CO_2, %
	(A)	(B)	(C)	(D)	(E)
1	47(30-77)	14.85(13.67-16.12)	4.92(4.05-6.02)	10.13(6.12-11.44)	6.72(5.28-8.08)

Contributor: Craig, F. N.

Reference: Hill, L., and Flack, M., J. Physiol., Lond. 37:77, 1908.

Section 2: Voluntary Hyperventilation

Subjects at rest.

	Total Ventilation L/min	Alveolar CO_2[1]	
		Constant Frequency %	Constant Tidal Volume %
	(A)	(B)	(C)
1	5	6.08	5.86
2	10	4.37	4.71
3	20	2.86	3.54
4	40	2.19	2.59

/1/ Recalculation of published data.

Contributor: Craig, F. N.

Reference: Sunahara, F. A., Girling, F., Snyder, R. A., and Topliff, D., J. Aviat. M. 28:13, 1957.

Part II: EXERCISE

Section 1: Effect on Expired and Alveolar CO_2

	Condition	O_2 Uptake L/min	Total Ventilation L/min	CO_2	
				Expired Air %	Alveolar Air %
	(A)	(B)	(C)	(D)	(E)
1	Rest, bed	0.24	7.7	3.19	5.97
2	Rest, standing	0.33	10.4	3.14	5.70
3	Walking	0.67	16.3	4.25	6.04
4		1.07	24.8	4.62	6.10
5		1.60	37.3	4.67	6.36
6		2.01	46.5	4.72	6.20
7		2.54	60.9	4.79	6.10

Contributor: Craig, F. N.

Reference: Douglas, C. G., and Haldane, J. S., J. Physiol., Lond. 45:235, 1912-1913.

Section 2: Effect on Composition of Expired Air

Bicycle ergometer.

	O_2 Uptake L/min	Total Ventilation L/min	Expired Air[1]	
			O_2, %	CO_2, %
	(A)	(B)	(C)	(D)
1	0.25	6.5	17.05	3.29
2	0.50	10.5	16.35	3.99
3	1.00	20.0	16.00	4.54
4	1.50	30.0	15.95	4.84
5	2.00	42.5	16.15	4.80
6	2.50	56.5	16.65	4.34

/1/ Recalculation of published data.

Contributor: Craig, F. N.

Reference: Bock, A. V., Vancaulaert, C., Dill, D. B., Folling, A., and Hurxthal, L. M., J. Physiol., Lond. 66:136, 1928.

Part II: EXERCISE (Concluded)

Section 3: Effect on Composition of Expired Air, Exercise vs Recovery

Treadmill experiment. O_2 consumption three times basal.

	Conditions	O_2, %[1]	CO_2, %[1]
	(A)	(B)	(C)
	Male		
1	Rest	16.77	3.95
2	Exercise	15.78	4.68
3	Recovery	16.81	4.27
	Female		
4	Rest	17.09	3.47
5	Exercise	16.09	4.18
6	Recovery	17.09	3.86

/1/ Recalculation of published data.

Contributor: Craig, F. N.

Reference: Bruce, R. A., Pearson, R., Lovejoy, F. W., Yu, P. N., and Brothers, G. B., J. Clin. Invest. 28:1431, 1949.

Section 4: Effect on Blood Lactic Acid and Composition of Alveolar Air

Bicycle ergometer.

	O_2 Uptake L/min	Alveolar[1] O_2, %	Alveolar[1] CO_2, %	Blood Lactic Acid mEq/L
	(A)	(B)	(C)	(D)
1	0.4	14.55	5.47	1.2
2	0.8	14.75	5.40	1.3
3	1.2	14.06	5.96	1.6
4	1.6	13.99	6.24	2.2
5	2.0	14.33	6.17	3.7
6	2.2	14.75	5.96	5.1

/1/ Recalculation of published data.

Contributor: Craig, F. N.

Reference: Dill, D. B., Edwards, H. T., Folling, A., Oberg, S. A., Pappenheimer, A. M., Jr., and Talbott, J. H., J. Physiol., Lond. 71:48, 1931.

Part III: HEAT

Section 1: Increased Body Temperature; Subjects at Rest in Hot Baths

Four subjects. O = oral, R = rectal.

	Temperature Body, °C	Temperature Bath, °C	Alveolar[1] O_2, %	Alveolar[1] CO_2, %	Total Ventilation L/min
	(A)	(B)	(C)	(D)	(E)
1	36.8 O		14.82	5.58	7.0
	39.7 O	42	17.82	3.27	18.0
2	38.2 R	37	14.87	5.46	8.5
	39.3 R	41	16.04	3.36	38.0
3	37.8 R		15.61	4.93	5.0
	39.2 R	43	16.04	3.10	39.0
4	36.7 O		13.36	6.58	9.5
	39.2 O	42	16.11	3.82	25.5

/1/ Recalculation of published data.

Contributor: Craig, F. N.

Reference: Hill, L., and Flack, M., J. Physiol., Lond. 38:57, 1909.

Section 2: Increased Body Temperature during Exercise

Bicycle ergometer. Room temperature, 34°C.

	Exercise min	Rectal Temperature °C	Total Ventilation L/min	O_2 Uptake L/min	Alveolar CO_2[1] %
	(A)	(B)	(C)	(D)	(E)
1	10	38.0	45	2.1	6.17
2	20	38.4	47	2.1	5.90
3	30	38.8	48	2.1	5.47
4	40	39.2	50	2.1	5.34
5	50	39.6	52	2.1	5.19

/1/ Recalculation of published data.

Contributor: Craig, F. N.

Reference: Dill, D. B., Edwards, H. T., Bauer, P. S., and Levenson, E. J., Arbeitsphysiologie 4:508, 1931.

Part IV: CO_2 INHALATION

Section 1: Various Exposure Times

Subjects at rest. R.Q. = respiratory quotient.

	CO_2 Inhalation min	Total Ventilation L/Min	Inspired		Expired		O_2 Uptake cc/min	CO_2 Output cc/min	R.Q.
			O_2, %	CO_2, %	O_2, %	CO_2, %			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	0	7.3	20.93	0.03	16.76	3.38	318	243	0.77
2	3	33.8	19.42	5.83	18.24	6.48	446	206	0.46
3	11	43.2	19.27	5.99	18.30	6.54	466	225	0.48
4	18	46.6	19.11	6.10	18.24	6.75	447	293	0.66

Contributor: Craig, F. N.

Reference: Campbell, J. M., Douglas, C. G., Haldane, J. S., and Hobson, F. G., J. Physiol., Lond. 46:301, 1913.

Section 2: Various Concentrations

	Inspired CO_2 %	Total Ventilation L/min	Alveolar CO_2[1] %
	(A)	(B)	(C)
1	0.18	12.9	6.34
2	1.02	16.6	6.45
3	2.22	15.6	6.69
4	4.17	27.2	6.83
5	5.31	41.1	6.99
6	7.50	71.0	8.37

/1/ Recalculation of published data.

Contributor: Craig, F. N.

Reference: Barcroft, J., and Margaria, R., J. Physiol., Lond. 72:175, 1931.

Section 3: During Exercise

One subject.

	Time[1] min	Treadmill Speed mi/hr	Inspired		Expired		Total Ventilation L/min	O_2 Uptake L/min
			O_2, %	CO_2, %	O_2, %	CO_2, %		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	0	1.5	17.36	1.93	14.21	5.03	15.0	0.43
2	16	1.5	16.54	4.36	14.20	6.37	22.0	0.47
3	31	1.5	15.81	6.45	14.60	7.47	37.5	0.41
4	52	3.0	17.36	1.93	13.95	5.06	24.0	0.75
5	63	3.0	16.54	4.36	14.04	6.65	35.0	0.78
6	81	3.0	15.81	6.45	14.03	8.07	51.5	0.82
7	104	4.0	17.36	1.93	13.78	5.42	36.0	1.17
8	121	4.0	16.54	4.36	13.69	6.95	47.0	1.20
9	150	4.0	15.81	6.45	13.39	8.50	60.0	1.32

/1/ Start of each test

Contributor: Craig, F. N.

Reference: Craig, F. N., J. Appl. Physiol. 7:467, 1955.

Part V: O_2 INHALATION

Section 1: Various Concentrations

	Inspired		Expired	
	O_2, %	CO_2, %	O_2, %	CO_2, %
	(A)	(B)	(C)	(D)
1	80.24	0.20	72.21	5.84
2	63.67	0.14	57.57	5.41
3	20.93	0.03	14.50	5.54
4	15.63	0.07	10.60	5.45
5	12.78	0.07	7.80	5.28
6	11.33	0.10	8.96	3.85
7	11.09	0.10	7.10	4.89
8	6.23	0.09	4.30	3.57

Contributor: Craig, F. N.

Reference: Haldane, J. S., and Priestley, J. G., J. Physiol., Lond. 32:225, 1905.

Part V: O_2 INHALATION (Concluded)

Section 2: N_2 in Expired Air

N_2 as an increment over the N_2 contained in an inspired gas mixture containing 1% of N_2 in O_2. Subjects at rest, submerged in water. Ranges in parentheses are estimate "c" of the 95% range (cf Introduction).

	Time on Gas Mixture min	N_2 Increment %
	(A)	(B)
1	1	0.76(1.58-0.41)
2	4	0.17(0.28-0.07)
3	8	0.15(0.18-0.11)
4	13	0.11(0.15-0.05)
5	30	0.08(0.15-0.05)
6	60	0.05(0.06-0.03)
7	90	0.04(0.07-0.02)

Contributor: Craig, F. N.

Reference: Blevins, W. V., Frankel, H., Garren, H., and Craig, F. N., Chemical Corps Medical Laboratories Research Rept. No. 216, Army Chemical Center, Maryland, 1953.

Part VI: ADDED RESISTANCE

The effect of added resistance on the composition of alveolar air. Resistance the same on inspiration and expiration.

	Resistance mm H_2O/cc/sec	O_2, %[1]	CO_2, %[1]
	(A)	(B)	(C)
1	0.077[2]	13.93	5.70
2	0.308	13.50	5.95
3	0.077[3]	14.18	5.60

/1/ Recalculation of published data. /2/ Before added resistance. /3/ After added resistance.

Contributor: Craig, F. N.

Reference: Cain, C. C., and Otis, A. B., J. Aviat. M. 20:149, 1949.

Part VII: ADDED DEAD SPACE

Average of three subjects.

	Added Dead Space L	Total Ventilation L/min	Expired		Alveolar	
			O_2, %	CO_2, %	O_2, %	CO_2, %
	(A)	(B)	(C)	(D)	(E)	(F)
1	0	8.6	17.93	3.00	15.92	4.79
2	1.0	17.7	19.41	1.51	15.52	4.90
3	2.0	28.9	20.02	0.86	14.40	5.95
4	3.0	38.8	20.34	0.54	10.32	6.99

Contributor: Craig, F. N.

Reference: Swann, H. E., Jr. (thesis), Univ. of Maryland, 1950.

Part VIII: ACIDOSIS

One subject.

	Day	Ingested NH_4Cl mM	Alveolar CO_2[1] %
	(A)	(B)	(C)
1	1	0	5.44
2	2	374	5.15
3	3	374	4.26
4	4	281	3.90
5	5	0	4.25
6	6	0	4.81
7	7	0	5.15
8	8	0	5.42

/1/ Recalculation of published data.

Contributor: Craig, F. N.

Reference: Haldane, J. B., J. Physiol., Lond. 55:265, 1921.

Part IX: ALKALOSIS

One subject.

	Time hr	Condition	Alveolar CO_2 %
	(A)	(B)	(C)
1		Control	5.8
2	0.5	Ingestion 57.5 g $NaHCO_3$	6.2
3	3.5	Peak excretion rate of $NaHCO_3$	6.8
4	8.5	Urine flow returned to normal	6.1

Contributor: Craig, F. N.

Reference: Davies, H. W., Haldane, J. B., and Kennaway, E. L., J. Physiol., Lond. 54:32, 1920.

Part X: INHALED PHOSGENE RETENTION

The amount retained is the difference between the amount inspired and the amount recovered in the expired air. That retained is expressed as a fraction of the amount inspired. Values in parentheses are estimate "c" of the 95% range (cf Introduction).

	Species	Retained Gas %	Reference
	(A)	(B)	(C)
1	Rhesus monkey	0.792(0.512-0.980)	1
2	Dog	0.740(0.518-0.937)	2
3	Goat	0.628(0.365-0.941)	3

Contributor: Craig, F. N.

References: [1] Weston, R. E., and Karel, L., J. Indust. Hyg. 29:29, 1947. [2] Weston, R. E., and Karel, L., J. Pharm. Exp. Ther. 88:195, 1946. [3] Karel, L., and Weston, R. E., J. Indust. Hyg. 29:23, 1947.

141. EFFECTS OF PULMONARY FIBROSIS ON PULMONARY FUNCTION: MAN

Ranges in parentheses are estimate "d" of the 95% range (cf Introduction).

R = rest, E = exercise.

	Disease[1]	No. of Subjects, Dynamic Status	Maximal Breathing Capacity[2] %	Vital Capacity[2] %	Residual Volume[2] %	O_2 Ventilatory Equivalent %[2, 3]	Alveolar O_2 Pressure[4, 5] mm Hg	Arterial Blood: Partial Pressure O_2[4] mm Hg	Arterial Blood: Partial Pressure CO_2[4] mm Hg	Arterial Blood: O_2 Saturation %[4]	O_2 Diffusing Capacity[4, 6] ml/min/mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
1	Extensive parenchymal tuberculosis[7]	62 R	80(40-110)	80(40-110)	110(50-150)		90(80-110)	70(65-90)	39(34-42)	90(85-97)	15(6-20)	1, 4-6, 13, 24
2		E				120(100-150)	100(95-105)	65(60-85)	39(30-39)	88(80-94)		
3	Tuberculous pleuritis, "fibrothorax"	18 R	60(40-80)	50(25-60)	60(30-80)		80(80-110)	70(50-80)	39(30-42)	90(80-92)		2, 3
4		E				130(100-170)						
5	Widespread bronchiectasis	12 R	90(50-100)	80(40-100)	100(50-100)		90(80-110)	70(60-90)	39(34-42)	90(80-92)	18(15-25)	5,24
6	Silicosis[8]	110 R	90(70-120)	80(50-110)	110(80-180)		90(80-100)	75(65-90)	39(34-45)	92(85-95)	14(9-25)	5, 6, 9, 11, 15, 21, 24
7		E				120(100-160)	110(95-115)	70(60-80)	38(34-40)	88(80-92)	16(13-22)	
8	Idiopathic fibrosis[9]	27 R	80(60-110)	70(50-90)	90(80-180)		100(90-105)	60(30-80)	35(30-40)	80(60-85)	9(5-12)	5, 15, 19, 22, 24, 26
9		E				140(110-160)	110(105-115)	50(30-80)	34(30-40)	75(50-90)	15(12-18)	
10	Widespread sarcoidosis	58 R	80(50-170)	65(35-120)	80(60-120)		100(95-102)	85(64-90)	38(35-41)	88(80-96)	10(6-16)	6-8, 15, 17, 23-26
11		E				150(110-170)	110(105-115)	65(40-85)	37(32-42)	85(75-97)	15(10-17)	
12	Beryllium granulomatosis	36 R	90(70-120)	60(40-80)	80(70-110)		105(95-110)	70(60-90)	38(35-42)	90(88-96)	8(5-10)	6,15,20,21, 26
13		E				160(120-300)	112(100-120)	55(30-80)	35(30-40)	75(60-85)	15(12-25)	
14	Hamman-Rich syndrome	3 R	65(50-100)	50(40-60)	50(40-60)					80(70-90)		10,15,18
15		E				160(150-200)	114	35	41	87	14	
16	Diatomaceous earth fibrosis	30 R	103(70-120)	106(95-130)	113(70-160)		97(85-105)	91(80-110)	41(35-50)	95(90-97)		12
17										93(90-96)[10]		
18	Asbestosis	57 R	90(70-100)	70(60-90)			85(80-100)	75(65-90)	40(35-42)	92(88-96)		16,24
19		E				150(120-180)	95(90-100)	60(50-80)	38(35-40)	88(70-90)		

/1/ Data on cases with severe pulmonary emphysema not included. /2/ Results expressed in % of predicted normal. /3/ Ventilatory equivalent for O_2 = minute volume (BTPS)/O_2 uptake (STPD). /4/ Breathing air at sea level. /5/ Calculated from alveolar equation and assumption that CO_2 arterial pressure = CO_2 alveolar pressure. /6/ Determined by Riley's method [26] or by Filley's D_{CO} method [27]; $DO_2 = D_{CO} \times 1.23$, ml O_2/min/mm Hg. /7/ Without pleural thickening. /8/ Most patients reviewed had 1st or 2nd stage silicosis only, since 3rd stage is so often complicated by emphysema. /9/ Not classifiable as Hamman-Rich syndrome. /10/ Blood sampled after, rather than during, exercise.

Contributors: (a) Filley, G. F., (b) Armstrong, B. W., (c) Nims, R. G.

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142. COMPARATIVE PATHOLOGY OF THE PNEUMOCONIOSES

The term pneumoconiosis is used in a generic sense to include the deposition of any insoluble exogenous particles in lung tissue, regardless of the presence or absence of sequellae. There are many more pneumoconioses than the ones here listed, including those considered benign or asymptomatic [1], and those manifestly of a mixed variety in which silica is the more significant component. It must be strongly emphasized that the tabulation here presented should be considered to apply to the respective pneumoconioses only when they are of moderate severity. It is obvious that the amount of anatomic, physiologic, and immunologic alteration depends largely upon whether the involvement by the particular pneumoconiosis is mild, moderate, or severe. Any other application of this tabulation would be misleading and result in confusion.

	General Effect	Specific Effect	Anthracosis	Silicosis	Asbestosis	Chronic Berylliosis	Bauxite Fume Pneumoconiosis (Shaver's Disease)	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Anatomic	Emphysema	+	+	+	+	+	C,3-5;D,6;E,7; F,8-11;G, 12-14
2		Hilar fibrosis	0	+	0	?	+	D,15;G,12-14
3		Nodular fibrosis	0	+	0	+	0	D,15,16;F,8-11; G,12-14
4		Alveolar fibrosis	0	0	+	+	+	C,5,17,18;D, 19-22;E,23; F,8-11;G, 12-14
5		Vascular sclerosis	0	+	+	+	+	D,6,24;E,25;F, 8-11,G,12-14
6		Pleural fibrosis	0	+	+	+	+	E,7;F,8-11;G, 12-14
7		Granulomatous inflammation	0	0	0	+	0	F,8-11;G,12-14
8	Physiologic	Reduced ventilatory movements	+	+	+	+	+	C,26,27;D,28; E,23;F,8-11, G,12-14
9		Reduced respiratory surface	0[1]	+	0	+	+	C,5,17,18; F, 8-11;G,12-14
10		Impaired gaseous diffusion	0	0[2]	+	+	+	F,8-11;G,12-14
11		Pulmonary hypertension (cor pulmonale)	+	+	+	+	+	C,27;F,8-11;G, 12-14
12	Immunologic[3]	Increased susceptibility to tuberculosis	?	+	?	?[4]	?[4]	C,3-5,17,18;D, 19;E,7,19,29, 30
13		Increased incidence pulmonary cancer	0	0	?	?[4]	?[4]	D,19,29;E,29, 31,32

/1/ Only in cases of progressive massive fibrosis. /2/ Except in the presence of diffuse alveolar fibrosis. /3/ The propriety of classifying the increased incidence of pulmonary cancer under the heading of immunologic effect is debatable; it is done here for the sake of convenience and simplicity. /4/ Total number of cases reported is too small.

Contributor: Gross, P.

References: [1] Sander, O. A., in "Clinical Cardiopulmonary Physiology," ed. Gordon, B. L., p 350, New York: Grune and Stratton, 1957. [2] Di Biasi, W., Virchows Arch. 319:505, 1951. [3] Heppleston, A. G., J. Path. Bact., Lond. 59:453, 1947. [4] Fletcher, C. M., in "ILO 3rd Internat. Conf. of Experts on Pneumoconiosis, Sydney, 1950; Record of Proceedings," vol 2, p 150, Geneva: International Labor Office, 1953. [5] Hart, P. D., and Aslett, E. A., in "Chronic Pulmonary Disease in South Wales Coalminers," Special Rept. Series No. 243, vol I, London: Medical Research Council, 1942. [6] Matz, P. B., Am. J. M. Sc. 196:548, 1938. [7] Stone, M. J., Am. Rev. Tuberc. 41:12, 1940. [8] Hardy, H. L., in "Pneumoconiosis," 6th Saranac Symposium, Trudeau School of Tuberculosis, ed. Vorwald, A. J., et al, p 133, New York: Paul B. Hoeber, Inc., 1950. [9] Wright, G. W., ibid, p 173. [10] Vorwald, A. J., ibid, p 190. [11] Vorwald, A. J., in "Clinical Cardiopulmonary Physiology," ed. Gordon, B. L., p 359, New York: Grune and Stratton, 1957. [12] Wyatt, J. P., and Riddell, A. R., Am. J. Path. 25:447, 1949. [13] Riddell, A. R., in "Pneumoconiosis," 6th Saranac Symposium, Trudeau School of Tuberculosis, ed. Vorwald, A. J., et al, p 459, New York: Paul B. Hoeber, Inc., 1950. [14] Shaver, C. G., and Riddell, A. R., J. Indust. Hyg. 29:145, 1947. [15] Di Biasi, W., Tuberkulosearzt 7:343, 1953. [16] Gardner, L. U., Pub. Health Rept., Wash. 50:695, 1935. [17] Gough, J., J. Path. Bact., Lond. 51:277, 1940. [18] Fletcher, C. M., in "Beiträge zur Silicose-Forschung; Bericht über die Medizinischwissenschaftliche Arbeitstagung über Silicose," (Sonderband) p 119, Bochum: Bergbau-Berufsgenossenschaft, 1951. [19] Union of South Africa Rept. of the Departmental Committee of Enquiry into the Relationship between Silicosis and Pulmonary Disability and the Relationship between Pneumoconiosis and Tuberculosis, Pretoria: The Government Printer, 1955. [20] Gardner, L. U., J. Indust. Hyg. 14:18, 1932. [21] Gardner, L. U., ibid 19:111, 1937. [22] Vigliani, E. C., and Mottura, G., Brit. J. Indust. M. 5:148, 1948. [23] Di Biasi, W., Arch. Gewerbepath. 8:139, 1937. [24] Geever, E. F., Am. J. M. Sc. 214:292, 1947. [25] Vorwald, A. J., personal communication. [26] Motley, H. L., in "Clinical Cardiopulmonary Physiology," ed. Gordon, B. L., p 331, New York: Grune and Stratton, 1957. [27] Levine, E. R., and Liu, C. K., ibid, p 447. [28] Rossier, P. H., in "ILO 3rd Internat. Conf. of Experts on Pneumoconiosis, Sydney, 1950; Record of Proceedings," vol 2, p 26, Geneva: International Labor Office, 1953. [29] Merewether, E. R. A., ibid, vol 1, p 32. [30] Cartier, P., ibid, vol 1, p 32. [31] Lynch, K. M., McIver, F. A., and Cain, J. R., Am. M. Ass. Arch. Indust. Health 15:207, 1957. [32] Isselbacher, K. J., Klaus, H., and Hardy, H. L., Am. J. M. 15:721, 1953.

143. PHYSIOLOGIC CLASSIFICATION OF HYPOXIAS

Hypoxias are presented in four major groups: (1) Anoxic. Failure in oxygenation of pulmonary blood flow (low pO_2 in pulmonary venous blood). (2) Hemic. Lack of oxygen-carrying capacity of blood. (3) Circulatory. Failure in mechanics of delivery of normally oxygenated blood. (4) Histotoxic. Cellular toxicity interfering with oxygen utilization.

	Type (A)	Cause (B)	Mechanism (C)	Clinical State (D)	Reference (E)
			Anoxic		
1	Ambient	Dilution of oxygen	Lowered pO_2 in inspired air.	Fire damp, black damp.	1,7
2		Rarified atmosphere		Mountain sickness, high altitude blackout.	2-7
3		Selective reduction O_2		In experimental studies, anesthesia accidents.	5-7
4	Respiratory	Ventilatory insufficiency	Lowered pO_2 in alveolar air.	Obstructive lesions: emphysema, bronchospasm, respiratory tract obstruction, paralysis of respiratory muscles, tetanus, strychnine poisoning. Space-occupying lesions: pneumothorax, pleural effusions, certain consolidations, thoracic cage deformity. CNS depression from drugs, anesthetics, CNS lesions.	8,9,14
5		Alveolar wall block	Impaired alveolo-capillary diffusion.	Fibrosis or edema of alveolar wall; infection, pneumoconiosis, mitral stenosis, left ventricular failure.	8,10
6		Physiologic intrapulmonary shunt	Blood passage through non-ventilated segments of lung.	Certain consolidations, incomplete bronchial obstruction.	11
7		Pulmonary arterio-venous shunt	Shunt of unoxygenated blood around normal alveoli.	Pulmonary hemangioma or arterio-venous shunt.	12
			Hemic		
8	Anemic	Reduction in total circulating hemoglobin	Decreased concentration of oxygen in whole blood.	Anemias of blood loss, deficiency state, hemolysis or bone marrow depression.	13,14
9	Toxic	Reduction in functional circulating hemoglobin	Conversion of Hb into COHb, metHb or sulfHb.	Toxicity of CO, nitrites, chlorates, various coal tar derivatives; rare congenital metabolic disorders.	14,15
			Circulatory		
10	Volumetric	Blood volume loss	Low circulating blood flow.	Shock associated with hemorrhage, burns, trauma or infection.	16
11		Volume capacity increase		Peripheral vascular collapse, states with sequestration of blood.	16
12	Cyanotic congenital cardiac	Anomalous inflow or outflow routes of the heart	Routing of venous blood into left atrium or aorta.	Anomalous vena caval drainage, transposition of great vessels, persistent truncus arteriosus.	17,18
13		Absence of one or more cardiac chambers	Mixing of bloods in common cardiac chamber.	Cor biloculare, cor triloculare biatriatum.	18
14		Abnormal communication between lesser and greater circulations	Ejection of venous blood into left heart or into aorta (right to left shunt).	Fallot type: pulmonary or tricuspid stenosis, or atresia with interatrial or interventricular communication. Eisenmenger type: pulmonary hypertension with "reverse" shunt through atrial septal defect, ventricular septal defect or persistent ductus arteriosus.	18-20
15	Minute flow discrepancy	Myocardial fault	Low cardiac output resulting from diseased myocardium.	Heart failure, myocardial infarction, myocarditis.	21-24
16		Constrictive lesion of heart	Low cardiac output resulting from poor diastolic filling.	Cardiac tamponade, constrictive pericarditis, arrhythmia, thoracic wall deformity.	25-27

17	Minute flow discrepancy (concluded)	Obstructive lesion of heart	Low cardiac output resulting from high resistance to flow.	Heart valve lesions, increased pulmonary or systemic vascular resistance.	19,27
18		Relative minute flow insufficiency	Oxygen demands of tissues in excess of minute flow supply.	Beriberi, thyrotoxicosis, arterio-venous fistula.	27,28
19	Peripheral vascular	Arterial obstruction	Distal ischemia.	Coarctation of aorta, atherosclerosis, thrombosis, embolism, arteritis, arteriolitis; laceration, division, extrinsic pressure on artery.	29-32
20		Venous stasis	Peripheral congestion.	Congestive heart failure, venous obstruction, venous valve incompetence.	32
21		Lymph stasis	Low capillary blood flow as a result of high tissue tension	Chronic infection of lymphatics, general edematous states, idiopathic.	32
22		Vasospastic states	Distal ischemia resulting from abnormal degree of angiospasm.	Raynaud's disease, arterial or venous spasm, certain cold injuries.	32-34
			Histotoxic		
23	Enzymatic	Specific enzyme poisoning	Failure of oxygen utilizing enzymes.	Cyanide poisoning.	35
24	Imbalance	Water and electrolyte imbalance	Distorted cellular chemistry.	Hyponatremic states.	14,36,37

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Dyspnea is defined as breathing associated with effort or distress, including subjective breathlessness and objective evidence of labored breathing.

Part I: GENERAL CAUSES

1	Abnormal hemoglobins	10	Fear
2	Acidosis	11	Increased body metabolism
3	Anemia	12	Neuromuscular defects
4	Apprehension	13	Pain
5	Cardiac and respiratory congenital deformities	14	Pulmonary edema
6	Congestive heart failure	15	Pulmonary embolism
7	Exercise	16	Pulmonary fibrosis
8	Exhaustion	17	Pulmonary infection
9	Fatigue	18	Respiratory obstruction, acute and chronic

Contributor: Tomashefski, J. F.

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Part II: MECHANISMS INVOLVED

	General (A)	Specific (B)	Reference (C)
1	Breathing: decreased capacity	Anatomical restriction of ventilation. Decreased lung compliance. Increased effort of breathing. Mechanical airway resistance.	1, 2
2	Breathing: increased work of	Oxygen consumption of respiratory muscles large in relation to flow of oxygen through these muscles.	1, 3, 4
3	Lungs: decreased diffusing capacity	Alveolar-capillary block. Loss of lung tissue and decreased diffusing surface area.	5, 6
4	Lungs: impaired distribution of air and blood	Altered ventilation perfusion relationships. Decreased effective alveolar ventilation. Increased respiratory dead space.	5, 7, 8, 9
5	Neuroanatomical; neurophysiological	Central receptors: thalamic and cortical centers. Mechanoreceptors, chemoreceptors: sensory receptors possibly located in lung parenchyma, airways, joints, muscles, aortic and carotid bodies.	10, 11
6	Physiochemical	Alterations of ventilation or respiratory drive. Increased respiratory stimulation as seen with hypercapnia, hypoxia.	11, 12
7	Tissue level: impaired gas transport and exchange		a

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145. O_2 CONSUMPTION: PROTOZOA

Like our other tables covering oxygen consumption, this one should be used with utmost caution and circumspection. The figures reflect order of magnitude; often a value may not prove accurate for a particular requirement. The table, however, does have special utility as an annotated bibliography. Values, unless otherwise specified, are cubic millimeters oxygen per million cells per hour for mature protozoa. B = bloodstream; C = culture; G = in presence of glucose.

	Species	Temp °C	Rate	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)
1	Balantidium coli	37	9.40[1]	C; G.	1
2		28	4.23[1]	C; G.	1
3	Leishmania brasiliensis	28	0.42	C; G.	2,3
4		32	0.32	C; G	2,3
5		37	0.65	C; G.	2,3
6	L. donovani	25	0.44	C; G.	2-5
7		28	0.18	C; G.	2-5
8		32	0.27	C; G.	2-5
9		37	0.38	C; G.	2-5
10	L. tropica	28	0.39	C; G.	2-4
11		32	0.31	C; G.	2-4
12		37	0.45	C; G.	2-4
13	Leptomonas ctenocephali	28	0.27[2]	C; G.	6
14	Paramecium calkinsi	25	250	Reactive for mating.	7
15		25	450	Non-reactive for mating.	7
16	Plasmodium cathemerium	38	0.10	1/4 grown; G.	8
17		38	0.25	3/4 grown; G.	8
18	P. cynomolgi	38	0.47	Segmenters; G.	8
19	P. inui	38	0.09	Rings, amebic.	8
20	P. knowlesi	38	0.08	Rings.	8
21		38	0.34	3/4 grown segmenters; G.	8
22	P. lophurae	38	0.18	1/2-3/4 grown; G.	8
23	Strigomonas fasciculata	28	0.37[2]	C; G.	6
24	S. oncopelti	28	0.41[2]	C; G.	6
25	Trichomonas foetus	28	2.15	C; G.	9
26	T. hepatica	38	6.00	C; G.	10
27	T. vaginalis	38	2.69	C; G.	11
28		38	0.96	C.	11
29	Trypanosoma congolense	37	1.53	B; G.	12
30	T. conorhini	28	0.26	C; G.	12
31	T. cruzi	28	0.44	B; G.	2,12
32		37	1.09	B; G.	2,12
33		37	1.24	B; G.	2,12
34		28	0.25	C; G.	2,3,13
35		32	0.43	C; G.	2,3,13
36		37	0.33	C; G.	2,3,13
37	T. equinum	37	1.66	B; G.	12
38	T. equiperdum	28	0.53	B; G.	2,12
39		37	0.91	B; G.	2,12
40		37	1.85	B; G.	2,12
41	T. evansi	37	1.66	B; G.	12
42	T. gambiense	37	1.70	B; G.	12
43		28	0.14	C; G.	2,12
44		30	0.38	C; G.	2,12
45		37	0.21	C; G.	2,12
46	T. hippicum	37	0.66	B; G.	2,14
47		38	2.00	B; G.	2,14
48	T. lewisi	37	0.69	B; G. Old.	2
49		37	0.50	B; G. Young.	15,16
50		37	125.5[3]	B, 4 da, untreated hosts; G.	17
51		37	92.4[3]	B, 4 da, treated hosts; G.	17
52	T. pipistrelli	30	0.13	C; G.	12
53	T. rhodesiense	28	0.77	B; G.	2,18
54		37	1.03	B; G.	2,18
55		37	1.94	B; G.	2,18

/1/ cu mm O_2 per 1,000 organisms per hr. /2/ Calculated from dry weight. /3/ cu mm O_2 per 2 x 10^8 organisms per hr.

Values, unless otherwise specified, are cubic millimeters oxygen per million cells per hour for mature protozoa. B = bloodstream; C = culture; G = in presence of glucose.

	Species	Temp °C	Rate	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)
56	Trypanosoma vivax, rat strain	36.5	1.17	B; G. Old.	19
57		36.5	2.00	B; G. Young.	19
58	T. vivax, sheep strain	36.5	0.63	B; G. Old.	19
		36.5	2.82	B; G. Young.	19

Contributors: (a) Silverman, M., (b) Vernberg, W. B., (c) Von Brand, T., (d) Wichterman, R., (e) Ivey, M.

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146. O_2 CONSUMPTION: HELMINTHS

Like our other tables covering oxygen consumption, this one should be used with utmost caution and circumspection. The figures reflect order of magnitude; often a value may not prove accurate for a particular requirement. The table, however, does have special utility as an annotated bibliography. Values, unless otherwise specified, are cubic millimeters oxygen per milligram dry substance per hour for adult animals. G = in presence of glucose.

	Species	Temp °C	Rate	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)
1	Ascaridia galli	37	2.5		1
2	Ascaris lumbricoides	30	0.38	Eggs, 0-2 da.	2
3		30	0.80	Eggs, 10-20 da.	2
4		30	0.15	Eggs, 45 da.	2
5		37	0.82[1]	Small.	3
6		37	0.33[1]	Large.	3
7		37	0.59[1]	Males.	4
8		37	0.32[1]	Females.	4,5
9		39	0.42[1]	Small.	6
10	Diphyllobothrium latum	37	2.7	Proglottids.	7
11		37	15.0	Proglottids, G.	7
12		22	0.34	Plerocercoids, G.	7
13		22	0.67	Plerocercoids, G.	7
14	Euplanaria tigrina	20	1.8	Starved.	8
15		20	1.4	Normal fed.	8
16		25	2.0	Starved.	8
17		25	2.2	Normal fed.	8
18		30	2.5	Normal fed.	8
19		35	3.5	Starved.	8
20		35	2.6	Normal fed.	8
21	Eustrongylides ignotus	37	0.56[1]	Larvae.	9
22	Fasciola hepatica	37.5	1.94		1
23	Gorgoderina attenuata	21	0.40		10
24	Gynaecotyla adunca	23.6	0.13[2]		11
25		30.4	0.29[2]	In air.	11
26		30.4	0.13[2]	In 5% O_2.	12
27		30.4	0.10[2]	In 100% O_2.	12
28	Haemonchus contortus	30	9.7	Eggs (morula).	1
29		30	10.7	Eggs (blastula).	1
30		30	12.6	Larvae.	1
31	Heterakis spumosa	38	4.0		13
32	Monieza expansa	37.5	1.1	Head region; G.	14

/1/ Calculated on dry matter percentage. /2/ Based on volume determinations.

Values, unless otherwise specified, are cubic millimeters oxygen per milligram dry substance per hour for adult animals. G = in presence of glucose.

	Species	Temp °C	Rate	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)
33	Monieza expansa (concluded)	37.5	0.9	Mature proglottids; G.	14
34		37.5	0.6	Gravid proglottids; G.	14
35	Nematodirus spp	37	5.1		1
36	Neoaplectana glaseri	30	12.6		1
37	Nippostrongylus muris	30	18.4	Larvae, 1 da.	1
38		30	13.0	Larvae, 4 da.	1
39		30	9.2	Larvae, 12 da.	1
40		37	6.8		1
41	Ostertagia circumcincta	38	7.4		13
42	Paramphistomum cervi	38	0.03		13
43	Planaria alpina	5	30		15
44		15	240		15
45	P. gonocephala	5	40		15
46		15	170		15
47	Schistosoma mansoni	37.5	6.0	Pairs.	16
48		37.5	8.7	Pairs; G.	16
49		37.5	9.1	Males; G.	16
50		37.5	10.7	Females; G.	16
51			8.5	Pairs, untreated hosts; G.	17
52			2.9	Pairs, treated hosts; G.	17
53	Strongylus equinus	38	3.3		13
54	S. vulgaris	38	3.6		13
55	Syphacia obvelata	38	4.4		13
56	Tetrameres confusa		0.24		18
57	Trichinella spiralis	37.5	2.35	Larvae	19
58		37.5	2.37	Larvae; G.	19

Contributors: (a) Chang, S. L., (b) Silverman, M., (c) Vernberg, W. B., (d) Von Brand, T., (e) Sawaya, P.

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Like our other tables covering oxygen consumption, this one should be used with utmost caution and circumspection. The figures reflect order of magnitude; often a value may not prove accurate for a particular requirement. The table, however, does have special utility as an annotated bibliography. Values, unless otherwise specified, are cubic millimeters oxygen per gram fresh weight per hour for adult animals.

	Class and/or Species	Temp °C	Rate	Reference
	(A)	(B)	(C)	(D)
	Porifera			
1	Suberites massa	22.4	24.1	1
	Coelenterata			
	Hydrozoa			
2	Carmarina hastata	16	6.0	2
3		20	8.0	2
4		25	2.0	3
	Scyphozoa			
5	Aurelia aurita	13	3.4	4
6		17	5.0	4
7	Rhizostoma pulmo	16	7.2	2
8		26	15.3	5
	Anthozoa			
9	Anemonia sulcato	18	13.4	6
	Ctenophora			
10	Beroe ovata	16	5.0	2
11	Cestus veneris	16	2.6	2
12		25	25.0	3
	Echinodermata			
	Asteroidea			
13	Asterias rubens	15	30	7
14	A. rubens, Baltic Sea	15	21	8
15	A. rubens, North Sea	15	24	8
	Echinoidea			
16	Strongylocentrotus lividus	25	15	3
	Holothuroidea			
17	Holothuria impatiens	25	17	3
18	H. stellata	25	4	3
	Ophiuroidea			
19	Ophioderma longicauda	25	8	9
20		25	32	3
	Mollusca			
	Cephalopoda			
21	Eladone moschata	16	181	9
22		25	28	3
23	Octopus vulgaris	16	47	10
24		16	87	2
25		20	117	2
26		25	68	3
27		25	102	3
28	Sepia officinalis	15	320	3
	Gastropoda			
29	Aplysia limacina	16	30	9
30	Australorbis glabratus	10	16.5	11
31		30	133	11
32	Helix pomatia	20	94	12
33	Limax agrestis	20	350	13
34	Lymnaea stagnalis	10	36.7	11
35		20	123	11
36	Pleurobranchea meckeli	25	36	3
37	Pterotrachea coronata	16	7.8	2
38		20	11	2
39	Tethys leporina	16	12	2
40		20	15	2
	Pelecypoda			
41	Mytilus sp	20	22	14
42		22.3	55	15
43	M. edulis	14	13	10
44	M. galloprovincialis	25	18	3

Values, unless otherwise specified, are cubic millimeters oxygen per gram fresh weight per hour for adult animals.

	Class and/or Species	Temp °C	Rate	Reference
	(A)	(B)	(C)	(D)
	Annelida			
	Oligochaeta			
45	Glossoscolex sp, small	25	109	16
46	Glossoscolex sp, large	25	38	16
47	Limnodrilus claparedeanus	18.5	496	17
48	L. hofmeisteri	25	1010[1]	18
49	Lumbricus sp	18.5	64	19,20
50		20	170	13
51	L. communis	21.5	206	21
52	L. herculeus	10	45	22
53	L. terrestris	20.5	138	21
54	Pheretima hawaya, small	25	271	16
55	P. hawaya, large	25	60	16
56	Pontoscolex sp, small	25	272	16
57	Pontoscolex sp, large	25	145	16
58	Tubifex sp	25	200	23
59	Tubifex tubifex	18.7	408	17
	Polychaeta			
60	Arenicola sp	12	30	24
61	Chaetopterus pergamentaceus	15	8	25
62	Glycera siphonostoma	25	15	6
63	Nereis virens	15	26	25
64	Sabella pavonina	10	62	26
65		17	43	26
66	Spirographis spallanzani	25	135	27
	Sipunculoidea			
67	Sipunculus nudus	16	50	9
	Arthropoda			
	Crustacea			
68	Asellus sp (isopod)	17	348	28
69	A. aquaticus (isopod)	10	700	29
70	Astacus fluviatilis (crayfish)	15	30	30
71	A. leptodactylus (crayfish)	20	70	31
72	A. torrentium (crayfish)	20	100	32
73	Callianaxa subterranea	15	930	3
74	Carcinus maenus (shore crab)	15	625	3
75	Dronia vulgaris (crab)	15	3000	3
76	Emerita talpodia	20	112	33
77	Eriphia spinifrons	15	1828	3
78	Galathea squamifera (crab)	15	215	3
79	Homarus americanus (lobster)	15	507	25
80	Ilia nucleus	15	253	3
81	Maja verrucosa (crab)	15	1460	3
82	Ocypode albicans (ghost crab)	26	139	34
83	Pachygrapus marmoralus (shore crab)	15	1137	3
84	Paguristis maculata	15	1600	3
85	Palaemon serratus (prawn)	16	106	9
86	P. squilla (prawn)	19	128	10
87	Palinurus vulgaris (rock lobster)	15	12,874	3
88	Pandalina brevirostrus	15	20	35
89	Pandalus montagui (prawn)	15	289	35
90	Pilumnus hirtellus	15	160	3
91	Pugettia producta (kelp crab)	15	100	36
92	Sicyonia sculpa	15	443	3
93	Spirontocaris cranchi	15	6	35
94	S. securifrons	15	349	35
95	Talorchestia meglopthalma (beach flea)	17	180	28
96		20	246	37
97	Trichodactylus petropolitanus	20	0.80[2]	38
98		20	0.19[1]	38
99		20	0.25[3]	38

/1/ Normal fed. /2/ Starved. /3/ Dry weight.

Values, unless otherwise specified, are cubic millimeters oxygen per gram fresh weight per hour for adult animals.

	Class and/or Species	Temp °C	Rate	Reference
	(A)	(B)	(C)	(D)
	Arthropoda (concluded)			
	Onychophora			
100	Epiperipatus brasiliensis	25	230	39
101	Peripatus accacioi	10	37	40
102		20	92	40
103		30	226	40
	Insecta			
104	Aedes aegypti (mosquito), ♂	26	2330	41
105	♀	26	4200	41
106	Anopheles quadrimaculatus (mosquito), ♂	26	2300	41
107	♀	26	2840	41
108	Apis mellifera, (hive bee)	20	17,466	42
109	True flight	20	87,000	43
110	Culex sp (mosquito)	20	575	45
111	C. pipiens, ♂	26	3430	41
112	♀	26	2580	41
113	Drosophila sp (fruit fly)	20	1560	46
114	True flight	20	21,800	46
115	D. repleta (fruit fly)	20	1680	47
116	True flight	20	21,000	47
117	Formica sp (ant)	20	532	48
118	Geotrupes sp	21	447	48
119	Limnophilus vittatus (trichopterid)	10	500	29
120	Lucelia sericata, true flight	20	95,600	49
121	Melanotus communis (click beetle)	21	1920	28
122		27	2400	28
123	Melolontha sp (beetle)	20	724	50
124		20	960	51
125	Musca sp (house fly)	20	3200	51
126		20	5112	42
127	M. domestica	20	1980	28
128	Passalus cornutus (beetle)	17	30	28
129	Periplaneta orientalis (cockroach)	20	277	12
130		25	450	51
131	Venessa sp (butterfly)	20	600	14
132	True flight	20	100,000	14
133	Zootermopsis angusticollis (termite)	20	400	52
134	Z. nevadensis (termite)	20	423	53

Contributor: Flemister, L. J.

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Like our other tables covering oxygen consumption, this one should be used with utmost caution and circumspection. The figures reflect order of magnitude; often a value may not prove accurate for a particular requirement. The table, however, does have special utility as an annotated bibliography. Values are cubic millimeters oxygen per gram fresh weight per hour for adult animals.

	Animal	Temp °C	Rate	Reference
	(A)	(B)	(C)	(D)
	Ascidicea			
1	Ascidia mentula	25	4.8	1
	Thaleacea			
2	Salpa max. africana	25	23.0	1
3	S. pinnata	16	8.0	2
4		20	12.0	2
5	S. tilesii	16	2.0	2
6		20	2.8	2
	Cephalochordata			
7	Amphioxus sp	25	149	1
8	A. lanceolatus	16	35	2
9		20	45	2
	Pisces			
10	Anguilla vulgaris (eel)	25	128	1
11	Arapaima gigas (pirarucus)	25	9	3
12	Astronotus ocellatus (cichlid)	20	1.3	4
13	Cichla temensis (cichlid)	20	0.9	4
14	Cobitis fossilis	20	51	5
15	Crenichthys baileyi	21	284	6
16		37	546	6
17	Cyprinus carassius (goldfish)	20	113	7
18	Resting	20	85	8
19	Active	20	160	8
20	C. carpio	19.5	100	9
21	C. tinca	20	104	10
22	Esox lucius (pike)	18	102	10
23	Heliasis chromis	16	93	2
24		20	162	2
25	Lepidosiren paradoxa (lungfish)	20	42	3
	Protopterus aethiopicus (African lungfish)			
26	Fasting	20	10	11
27	Feeding	20	52	11
28	Salmo trutta (trout)	15	226	10
29	Sargus rondeletti	25	375	1
30	Scomber scombrus (mackerel)	20	726	12
31	Serranus scriba	16	116	2
32		20	151	2
33	Sparus auratus	19	175	13
34	Spheroides maculatus (puffer)	20	62	14
35	Stenotomus chrysops (scup)	20	174	12
36	Tautog onitis (tautog)	20	62	12
37	Tautogolabus adspersus (cunner)	21	120	15
38		26	192	15
	Amphibia			
39	Molge sp	20	110	16
40	M. vulgaris (newt)	20	123	17
41	Rana esculenta	20	70	17
42	Winter	20	85	18
43	Summer	20	437	18
44	R. fusca, winter	20	100	19
45	Summer	20	210	19
46	R. mugiens	25.3	106	20
47	R. temporaria	16	86	17
48		20	89	17
49	Winter	19	85	18
50	Summer	19	554	18
51	Typhlonectes compressicauda (coecilid)	20	33	21

Values are cubic millimeters oxygen per gram fresh weight per hour for adult animals.

	Animal	Temp °C	Rate	Reference
	(A)	(B)	(C)	(D)
	Reptilia			
	Chelonia			
52	Malaclemys centrata (diamondback terrapin)	24	35	22
53	Testudo vicina (Galapogos tortoise)	17.2	8.9	23
54		22	22	23
	Crocodilia			
55	Alligator lucius	25	64	20
56	A. mississippiensis	19.5	7.5	23
57		22	8.9	23
	Squamata			
58	Anguis fragilis	20	40	17
59	Coluber natrix	20	92	16
60		20	150	24
61	Constrictor constrictor	16	4.9	23
62		22	10.0	23
63		30	24.0	23
64	Crotalus atrox	16	6.8	23
65		22	16.4	6
66		30	35.5	6
67	Drymarchon corais couperi (gopher)	16	10.1	23
68		22	20.0	23
69		30	47.0	23
70	Iguana tuberculata	22	22.2	23
71		30	52.0	23
72	Lacerta agilis	20	1980	25
73	L. viridis	25	170	20
74	Python molurus	16	6.2	23
75	P. reticulatum	22	12.2	23
76	P. sebae	30	26.7	23
77	Storeria dekayi, ♂	20	266	26
78	♀	20	183	26
	Aves			
79	Canary		2900	27
80	Chicken, ♀		630	28
81	Chicken, Rhode Island Red, day		497	29
82	Night		497	29
83	Dove		950	30
84	Duck		800	31
85	Goose		547	32
86			592	28
87	Hummingbird, at noon		17,000	33
88	At midnight		1000	33
89	Hummingbird (Calypte anna)	24	12,300	34
90	Hummingbird (Selasphorus sasin)	22	13,900	34
91	Pigeon		710	30
92	Sparrow		2100	27
	Arctic			
93	Bunting, snow (Plectrophenox nivalis)		3350	35
94	Gull, arctic (Larus hyperboreus)		1640	35
95	Jay, Canada (Perisoreus canadensis)		2725	35
96	Raven, arctic		940	35
	Tropical			
97	Hawk, night (Nyctidromas albicollis)		1750	35
98	Manakin (Pipra mentalis)		4620	35
	Wild			
99	Aluda arvenis	10	3512	36
100	Anthus pratensis	10	3614	36
101	Carduelis carduelis	10	5336	36
102	C. cannabina	10	4508	36
103	Chloris chloris	10	4671	36

Values are cubic millimeters oxygen per gram fresh weight per hour for adult animals.

	Animal	Temp °C	Rate	Reference
	(A)	(B)	(C)	(D)
	Aves (concluded)			
	Wild (concluded)			
104	Corturnix corturnix	10	2080	36
105	Emberiza calandra	10	3222	36
106	E. citrinella	10	4551	36
107	Fringilla coelebs	10	3621	36
108	Guardelis linaria	10	5566	36
109	Lullula arborea	10	3672	36
110	Passer montana	10	4427	36

Contributor: Flemister, L. J.

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149. O_2 CONSUMPTION: MAMMALS

Like our other tables covering oxygen consumption, this one should be used with utmost caution and circumspection. The figures reflect order of magnitude; often a value may not prove accurate for a particular requirement. The table, however, does have special utility as an annotated bibliography. Values are cubic millimeters oxygen per gram fresh weight per hour for adult animals, unless otherwise indicated.

	Animal	Rate	Remarks	Reference
	(A)	(B)	(C)	(D)
	Monotremata			
1	Anteater, spiny (Echidna sp)	1100		1
2	Platypus, duckbilled (Ornithorynchus sp)	460		1
	Marsupiala			
3	Cat, Australian native (Dasyurus sp)	560		1
4	Kangaroo, rat (Bettongia sp)	950		1
5	Opossum, Australian (Trichosaurus sp)	700		1

Values are cubic millimeters oxygen per gram fresh weight per hour for adult animals.

	Animal (A)	Rate (B)	Remarks (C)	Reference (D)
	Insectivora			
6	Shrew, long-tailed (Sorex c. cinereus)	13,700		2
7	Shrew, Monterey (S. trowbideii montereyensis)	7200		2
8	Shrew, short-tailed (Blarina brevicauda kirtlandi)	5200		3
9	Shrew, Sonoma (Sorex pacificus sonomae), ♂	6100		2
10	♀	5500		2
11	Shrew, wandering (S. v. vagrans)	8600		2
	Chiroptera			
12	Bat, big brown (Eptesicus f. fuscus)	800		3
13	Bat, little brown (Myotis l. lucifugus)	1500		3
	Edentata			
14	Armadillo	201		4
15	Sloth, three-toed (Choloepus sp)	216		5
16	Sloth, two-toed (Bradypus sp)	168		5
	Sirenia			
17	Manatee (Trichechus latirostris)	120		6
	Odontoceti			
18	Porpoise (Tursiops truncatus)	360		7
	Proboscidea			
19	Elephant, Indian, ♀	155	37 yr.	8
	Perissodactyla			
20	Horse	250		9
	Artiodactyla			
21	Cattle, ♀	184		10
22		390		9, 11
23	Pig	220		11
24	Sheep	220		10
25		340		9, 11
	Rodentia			
26	Dormouse (Myoxus arbor)	15	Hibernating.	12
27		852	Awake.	12
28	Guinea pig	816		10
29	Hamster (Cricetus auratus)	1050		12
30	Hamster, golden	70	Hibernating.	13
31		2900	Awake.	13
32	Lemming (Dicrostonyx groenlandicus rubicatus)	1700		14
33	Mouse (Mus sp)	2500	Resting.	9
34		20,000	Running.	9
35	Mouse, California harvest (Reithrodontomys megalotus longicaudus)	3800	Resting.	2
36	Mouse, deer	1650	Basal.	15
37	Mouse, deer (Peromyscus maniculatus)	3600	Resting.	3
38	Mouse, Gapper's redback (Clethrionomys g. gapperi)	3600	Resting.	3
39	Mouse, house	1530	Basal.	15
40	Mouse, house (Mus musculus)	3500	Resting.	3
41	Mouse, jumping (Zapus hudsonius americanus)	4200	Resting.	3
42	Mouse, kangaroo (Microdipodos megacephalus nastutus), ♂	3700		2
43	♀	3400		2
44	Mouse, meadow (Microtus p. pennsylvanicus)	3300	Resting.	3
45	Mouse, northern whitefoot (Peromyscus maniculatus gracilis)	3000	Resting.	3
46	Mouse, pine (Pitymys pinetorum scalopsoides)	4300	Resting.	3
47	Mouse, Rhoad's redbacked (Clethrionomys gapperi rhoadi)	3800	Resting.	3
48	Mouse, white	1600	Basal.	15
49	Mouse, white (Mus musculus)	3600	Resting.	3
50	Mouse, woodland jumping (Napaeozapus i. insignis)	3100		3
51	Rabbit	640		9
52		850		9
53	Rat (Rattus sp)	2000		1
54	♂	692	6-9 mo.	16
55	Rat, white (Rattus rattus)	770		17
56	Rat, jungle (Proechimys semispinosus)	1270		14
57	Squirrel, arctic ground (Citellus parryii)	600		14
58	Squirrel, flying (Glaucomys v. volens)	2000		3
59	Woodchuck (Marmota sp)	14	Hibernating.	18
60		262	Awake.	18

Values are cubic millimeters oxygen per gram fresh weight per hour for adult animals, unless otherwise indicated.

	Animal	Rate	Remarks	Reference
	(A)	(B)	(C)	(D)
	Carnivora			
61	Bear, polar (Thalarctos maritimus)	700	Cubs.	14
62	Cat (Felis catus)	710		9
63	Coati (Nasua navica)	500		14
64	Dog (Canis familiaris)	580		9
65		250	Young.	19
66	Dog, Eskimo (Canis familiaris)	785	Pups.	14
67	Fox, arctic white (Alopex lagopus)	505		14
68	Raccoon (Procyon carnivorous)	395		14
69	Seal (Phoco vitulina)	540		20
70	Seal (Phocaena communis)	300		21
71	Weasel (Mustela rixosa)	5000		14
	Primates			
72	Man (Homo sapiens)	220	Resting.	10
73		4000	Maximal work.	22
74	Marmoset (Leontocebus geoffroyi)	1040		14
75	Monkey, night (Aotus trivirgatus)	510		14

Contributor: Flemister, L. J.

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150. RESPIRATORY EXCHANGE CHARACTERISTICS: VERTEBRATES

Values in parentheses are estimate "c" of the 95% range (cf Introduction).

	Animal	Inspired Air[1] vol %		Expired Air[1] vol %		Respiratory Exchange[1] vol %		R.Q. CO_2/O_2	Reference
		O_2	CO_2	O_2	CO_2	O_2	CO_2		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Man	20.95	0.03	16.30	4.50	14.00	5.60	0.850	1
2	Dog (Canis familiaris)			16.30	3.46	13.66	5.68	0.780	2
3	Horse (Equus caballus)							0.960	3
4	Rat, albino (Rattus norvegicus)							0.894 (0.754-1.072)	4
5	Guillemot (Cepplus grylle)			15.05	4.83				5
6	Chicken (Gallus domesticus)			13.50	6.50			0.764 (0.71-0.96)[2]	6
7	Turtle (Malaclemys centrata)[3]					16.46	4.69	0.714[4]	7,8
8	Frog (Rana esculenta)[5]							1.92[6]	9
9								0.32[7]	9
10	Puffer fish (Spheroides maculatus)[5]	0.31[8]		0.149[8]		0.31[8]			10

/1/ Dry air. /2/ Average is for 5 days, including day of last feeding; range is for 1-5 hours, 4 days after feeding. /3/ 28°C. /4/ Calculated in part from data for painted turtle (Chrysemys marginata). /5/ 20°C. /6/ Cutaneous respiration. /7/ Pulmonary respiration. /8/ Sea water.

Contributor: McCutcheon, F. H.

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Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated. Fresh tissue was immersed in a buffered medium (phosphate or bicarbonate) in a closed chamber containing oxygen at 1 atmosphere pressure and maintained at 37°C (some determinations at 37.5° and 38°C). The decrease in amount of gaseous O_2 was measured as it was used by the tissue. As the rate of oxidation is limited by the amount of oxidizable nutrient available to the tissue, glucose or other nutrient was added, when necessary, to the medium.

Part I: BLOOD-FORMED ELEMENTS, BLOOD VESSELS, LYMPH NODES, MARROW, SPLEEN, THYMUS

	Tissue	Animal	Medium	Q_{O_2}	Reference
	(A)	(B)	(C)	(D)	(E)
1	Aorta	Man	Krebs phosphate	0.26	1
2			Krebs phosphate, glucose	0.10	2
3		Rat	Krebs-Ringer, glucose	1.03	3
4	Erythrocytes[1]	Man	Ringer glucose	0.045	4
5		Horse	Ringer glucose	0.06	5
6		Rabbit	Saline	0.008	6
7			Serum	0.10	7
8		Rat	Ringer glucose	0.038	8
9		Chicken embryo, 3 da	Ringer phosphate, glucose	0.47[2]	9
10		4 da		0.26[2]	9
11		6 da		0.14[2]	9
12		8 da		0.056[2]	9
13		9 da		0.044[2]	9
14		Chicken	Saline; Ringer glucose	0.14	4, 10, 11
15			Serum	0.30	12
16			Krebs-Ringer phosphate	0.17	13
17			Serum	0.58-1.79	14
18		Turtle	Saline	0.05	4, 10
19	Leucocytes	Man	Heparinized plasma	6.9	15
20			Serum, glucose	0.092[3]	6
21			Serum	2.6	16
22		Rabbit, exudate	Citrated Ringer's solution	4.0-4.6	17, 18
23			Serum	7.0	18
24		Rat	Serum	9.0-9.2	19, 20
25		Goose	Citrated plasma glucose	4.4	17
26	Marrow, bone	Rabbit	Ringer-bicarbonate-glucose, pH 6.4	2.8[4]	21
27			pH 7.2	3.7[4]	21
28			pH 7.6	2.6[4]	21
29	Erythroid cells		Serum	9 (approx.)	22
30	Myeloid cells			6 (approx.)	22
31		Rat	Neutralized serum	7.4[5]	23
32	All cells		Normal serum	42.0[5]	24
33	Nucleated cells			71.5[5]	24
34	Node, lymph	Man	Ringer glucose	3.8-5.9	25-27
35		Rat	Ringer glucose	4.4	28
36			Krebs-Ringer phosphate	0.87[6]	29
37	Reticulocytes	Rabbit	Ringer glucose	0.25	4, 10
38			Serum	1.75	12
39	Spleen	Guinea pig	Saline	8.3	30
40		Rat	Ringer glucose	7.2-12.9	8, 31-34
41			Serum	12.5	20
42			Krebs-Ringer phosphate	1.42[6]	29
43	Thrombocytes	Man	Citrated plasma glucose	6.2-8.4	15,19,35
44		Dog		5.1	35
45		Rat	Serum	6.0	20
46	Thymus	Rat	Ringer glucose	5.5-5.8	26, 28
47			Krebs-Ringer phosphate	1.09[6]	29
48		100 g	Ca-free Krebs-Ringer phosphate, glucose	0.76[6]	36
49		400 g		0.40[6]	36
50	Tonsil	Man	Ringer glucose	5.1	27

/1/ Additional information on erythrocyte oxygen consumption on Page 103, Table 85. /2/ cu mm oxygen per million cells per hr. /3/ Micromoles oxygen per 10 million white blood cells per hr. /4/ cu mm oxygen per mg cell protein per hr. /5/ cu mm oxygen per mg nitrogen per hr. /6/ cu mm oxygen per mg wet weight per hr.

Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part I: BLOOD-FORMED ELEMENTS, BLOOD VESSELS, LYMPH NODES, MARROW, SPLEEN, THYMUS (Concluded)

Contributors: (a) Vernberg, F. J., (b) Fitzgerald, L. R., (c) Barker, S. B., (d) Jandorf, B. J., (e) Quastel, J. H., and Scholefield, P. G.

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Part II: EPITHELIUM AND ASSOCIATED TISSUES

	Tissue (A)	Animal (B)	Medium (C)	Q_{O_2} (D)	Reference (E)
1	Adipose, brown fat	Rat	Ringer phosphate	0.419[1]	1
2	Retroperitoneal fat body			7.9[2]	2
3	White fat			0.049[1]	1
4	Cartilage, costal	Rabbit	Krebs-Ringer phosphate	0.41	3
5	Connective tissue cells, heart	Rat	Krebs phosphate	0.85[3]	4
6	Cornea	Rabbit	No suspending medium	0.864	5
7	Epithelium			6.25	5
8	Stroma			0.231	5
9	Dermis	Rabbit	Krebs phosphate	0.27	6
10	Intestine, duodenum	Hamster	Phosphate saline	22.7	7
11		Rat		23.0	7
12			Krebs-Ringer phosphate, glucose	3.6	8
13	Upper jejunum		Phosphate saline	21.5	7
14		Hamster		14.3	7
15	Lower ileum	Rat		13.5	7
16		Hamster		10.0	7
17	Mucosa, gastric	Man	Ringer glucose	9.6	9
18		Rat		7.2	10
19	Colon	Rabbit	Ringer glucose; serum	11.1	9
20		Rat	Ringer glucose	3.4-14.6	9, 11
21	Intestine			9.4-23.3	12, 13
22	Duodenum			8.8	11
23	Jejunum			15.6	11
24	Ileum			5.3	11
25	Uterus	Rabbit	Serum	6.1	14
26	Skin	Man	Ringer glucose	2.1(0.5-2.8)	15
27	Fetus		Ringer phosphate	1.8	16
28		Guinea pig	Ringer glucose	3.0	17

/1/ cu mm oxygen consumed per mg wet weight per hr. /2/ Micromoles oxygen consumed per g wet weight per hr. /3/ Micromoles oxygen consumed 1 million cells per hr.

Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part II: EPITHELIUM AND ASSOCIATED TISSUES (Concluded)

	Tissue (A)	Animal (B)	Medium (C)	Q_{O_2} (D)	Reference (E)
	Skin (concluded)				
29	Newborn	Mouse	Ringer glucose	6.1	18
30		Rat		3.5	18
31	10-36 da			4.9-3.6	19
32	79 da			1.8-2.0	19, 20
33	Ear	Guinea pig	Serum, Krebs-Ringer phosphate, glucose, streptomycin	1.05	21
34	Epidermis	Man	Ringer glucose	0.52-2.11	22
35	Ear	Guinea pig	Serum, Krebs-Ringer phosphate, glucose, streptomycin	5.29	23
36		Rat		3.69	23
37		Mouse		2.95	23
38	Dermis, ear			1.40	23
39		Rat		0.90	23
40		Guinea pig		2.21	23
41		Frog	Ringer phosphate (24.8°C)	0.96	24
42	Synovial membrane	Man	Krebs-Ringer phosphate	4.2[4]	25

/4/ cu mm oxygen consumed per mg nitrogen per hour.

Contributors: (a) Vernberg, F. J., (b) Fitzgerald, L. R., (c) Barker, S. B., (d) Jandorf, B. J., (e) Quastel, J. H., and Scholefield, P. G.

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Part III: GLAND TISSUES

	Tissue (A)	Animal (B)	Medium (C)	Q_{O_2} (D)	Reference (E)
1	Adrenal, cortex	Cattle, beef	Potassium phosphate, KCl, $MgCl_2$ adenylic acid	1.1	1
2	Medulla			0.6	1
3		Guinea pig	Serum	6.0	2
4			Potassium phosphate, KCl, $MgCl_2$ adenylic acid, citrate	0.8	1
5	Cortex			6.0	1
6		Mouse	Serum	6.0	2
7		Rat		10.0	2
8			Potassium phosphate, KCl, $MgCl_2$, potassium adenylate	1.1	3
9	Kidney	Guinea pig, 8 wk	Krebs-Ringer phosphate, glucose homogenates	4.06	4
10		50-52 wk		1.42	4
11		100 wk		1.15	4
12		Rat	Krebs-Ringer phosphate	3.72[1]	5
13			Ringer phosphate	16.3	6

/1/ cu mm oxygen consumed per mg wet weight tissue per hr.

Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part III: GLAND TISSUES (Concluded)

	Tissue (A)	Animal (B)	Medium (C)	Q_{O_2} (D)	Reference (E)
	Kidney (concl'd)	Rat (concluded)			
14	Cortex		Krebs-Ringer phosphate, glucose	11.61	7
15	Pancreas	Cat	Ringer glucose	6.0	8
16		Dog		3.2	9
17		Guinea pig	Saline	2.9	10
18		Rabbit	Ringer glucose	4.6	9
19		Rat	Saline	3.7	10
20			Ringer glucose	5.2	11
21			Krebs-Ringer phosphate	1.04[1]	5
22		Pigeon	Saline	8.7	10
23	Pituitary	Mouse	Serum	8.0	2
24		Rat, young		12.0	2
25	Anterior lobe	Rat	Ringer glucose	5.9	12
26			Krebs-Ringer phosphate	5.43	13
27	Posterior lobe		Ringer glucose	6.6	12
28			Krebs-Ringer phosphate	5.42	13
29	Salivary gland	Man	Ringer glucose	6.2	14
30		Guinea pig	Saline	5.0	10
31		Rat	Ringer glucose	9.7-24.2	11, 14
32			Krebs-Ringer phosphate	2.31[1]	5
33	Thyroid	Bull	Ringer phosphate	3.5	15
34		Bullock		3.1	15
35		Calf		2.8	15
36			Ringer glucose	2.6	16
37		Cow	Ringer phosphate	3.8	15
38		Dog	Serum	9.1	17
39			Ringer glucose	2.0	16
40		Hog		2.1	16
41		Rabbit	Ringer glucose, serum	11.7	14
42		Rat	Ringer glucose	12.5-13.0	9

/1/ cu mm oxygen consumed per mg wet weight tissue per hr.

Contributors: (a) Vernberg, F. J., (b) Fitzgerald, L. R., (c) Barker, S. B., (d) Quastel, J. H., and Scholefield, P. G.

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Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part IV: LIVER

	Animal (A)	Medium (B)	Q_{O_2} (C)	Reference (D)
1	Cow	Ringer glucose	2.6	1
2	Dog		6.0	2
3	Guinea pig	Saline	8.1	3
4		Ringer's solution	5.0	4
5	8 wk	Krebs-Ringer phosphate	1.14	5
6	50-52 wk		1.11	5
7	100 wk		0.97	5
8	Fatty liver	Ringer's solution	7.4	4
9	Horse	Ringer glucose	2.1	1
10	Mouse	Ringer's solution	18.7	6
11			8.8-13.8	7, 8
12		Krebs-Ringer phosphate	5.44	9
13	Rabbit	Ringer glucose	4.2-7.7	1, 10
14	Rat	Ringer's solution	7.0-10.2	11-13
15		Ringer glucose	6.5-11.6	1,6,7,12-19
16		Krebs-Ringer phosphate glucose	4.12	20
17			7.99	21
18		(37°C)	16.87[1]	22
19		(42°C)	23.80[1]	22
20		Krebs-Ringer phosphate	6.5	23
21	Castrate		5.2	23
22	Cold adapted	Locke's solution	19.25	24
23	Cold adapted	Locke's sodium glycerophosphate	9.19	25
24	Room temperature		7.87	25
25	Room temperature	Locke's solution	11.32	24
26	Fetus	Serum, Ringer glucose	7.1	14
27	3-21 da	Ringer glucose	13.2	26
28	10 g	Krebs-Ringer phosphate	11.0	27
29	300 g		8.0	27
30	Sheep	Ringer glucose	2.5	1
31	Chick, embryo, 6 da	Ringer glucose	7.5	28
32	12 da		4.5	28
33	20 da		1.5	28
34	Hen	Serum	14.5	29
35	Arctic cod	Ringer phosphate (25°C)	0.859[2]	30
36	Golden Orfe		0.792[2]	30
37	Menhaden	Phosphate buffer (30°C)	11.08[3]	31
38	Scup		14.87[3]	31
39	Toadfish		4.42[3]	31

/1/ cu mm oxygen consumed per 100 mg wet weight per 20 min. /2/ cu mm oxygen consumed per mg wet weight per hr. /3/ cu mm oxygen consumed per g wet weight per hr.

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Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part IV: LIVER (Concluded)

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Part V: LUNG

	Animal	Medium	Q_{O_2}	Reference
	(A)	(B)	(C)	(D)
1	Man, embryo	Ringer glucose	3.7	1
2	Cat		3.9	2
3	Guinea pig		6.1	2
4		Saline	7.4	3
5	Mouse	Ringer glucose	7.3-8.0	4
6			7.1	5
7	Rabbit		6.7	2
8	Rat, embryo	Serum	10.0	6
9	10 g	Krebs-Ringer phosphate	9.0	7
10	400 g		6.0	7
11	Adult	Saline	7.9	3
12		Ringer glucose	4.4-7.8	2, 8
13	Pigeon	Ringer glucose	3.6	2

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Part VI: MUSCLE TISSUES

	Tissue	Animal	Medium	Q_{O_2}	Reference
	(A)	(B)	(C)	(D)	(E)
1	Cardiac	Man	Krebs-Henseleit saline	2.5	1
2		Cat	Ringer glucose	0.68/1/	2
3			Ringer phosphate	1.30/1/	3
4	Atrium	Cattle, beef	Wollenberger	1.46/1/	4
5	Ventricle			1.48/1/	4
6	Conducting tissue			0.27/1/	4
7		Dog	Ringer glucose	0.94/1/	2
8		Young		4.2	5
9		Rat		3.8-10.4	6, 7
10			Ringer phosphate	2.7	8
11		10 g	Krebs-Ringer phosphate	12.0	9
12		400 g		6.9	9
13	Auricle		Ringer phosphate, glucose	8.8	10
14	Ventricle			9.5	10
15	Skeletal	Man	Modified Holiinger technique	0.24/2/	11
16		Rat	Ringer glucose	2.3-3.1	6, 7
17	Levator ani		Krebs-Ringer phosphate	3.50	12

/1/ μl oxygen consumed per mg wet weight per hr. /2/ ml oxygen consumed per 100 ml muscle per min.

Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part VI: MUSCLE TISSUES (Concluded)

	Tissue	Animal	Medium	Q_{O_2}	Reference
	(A)	(B)	(C)	(D)	(E)
18	Skeletal, (concluded)	Fish, scup	Phosphate buffer (30°C)	0.41[3]	13
19		Toadfish		0.727[3]	13
20		Menhaden		1.024[3]	13
21		Frog, resting	Ringer glucose	0.18-0.24	14-18
22		Electrical stimulation	Ringer's solution	0.79-4.24	15, 17
23		Pigeon	Saline	2.1	19
24	Papillary	Cat	Lock's solution, glucose	3.60	20
25	Diaphragm	Dog, young	Ringer glucose	1.9	5
26		Rabbit		2.4	5
27		Rat	Saline, Ringer's solution	4.1-5.9	6, 14, 19, 21, 22
28			Serum	5.9	22
29			Ringer phosphate	3.4	8
30			Ringer-Locke	0.97[1]	23
31			Krebs-Ringer phosphate	6.7	24
32				0.95[1]	25
33		10 g		15.0	9
34		300 g		4.4	9
35				6.3	12
36		Castrate		5.9	12
37	Smooth, gastric	Man	Ringer glucose	1.3	26
38		Rat		3.5	6
39	Intestinal	Cat		1.4	2
40		Frog		0.28	16
41		Rabbit		2.6	26
42		Rat	Saline	7.1	19
43			Ringer glucose	6.3	27
44	Jejunum		Ringer-Locke	1.26[1]	23
45	Seminal vesicles	Guinea pig	Ringer glucose	1.7	28
46		Castrate		1.4	28
47	Taenia coli	No tension	Ringer's solution	0.202	29
48		10 g tension		0.425	29
49	Uterine	Man	Ringer glucose	0.6	26

/1/ µl oxygen consumed per mg wet weight per hr. /2/ ml oxygen consumed per 100 ml muscle per min. /3/ µl oxygen consumed per g wet weight per min.

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Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part VII: NEOPLASMS

Section 1: Malignant

	Tissue	Animal	Medium	Q_{O_2}	Reference
	(A)	(B)	(C)	(D)	(E)
1	Adenocarcinoma	Mouse	Ringer glucose	6.1-26	1
2	Carcinoma, various	Man		2.0-7.9	2, 3
3	Flexner-Jobling	Rat	Ringer's solution, Ringer glucose	6.0-8.6	1-6
4	Earlis strain L cells		Krebs-Ringer phosphate, glucose	9.4	7
	Leukocytes, lymphatic leukemia	Man	Heparinized plasma		
5	Mature cells			6.1[1]	8
6	Mixed cells			2.6[1]	8
7	Immature cells			3.2[1]	8
	Leucocytes, myelogenic leukemia				
8	Mature cells			2.3[1]	8
9	Mixed cells			2.2[1]	8
10	Immature cells			3.2[1]	8
11	Sarcoma, A-274	Mouse	Krebs-Ringer phosphate, glucose	4.58	9
12	Crocker		Ringer glucose	9.7-14.8	10, 11
13	Various			8.5-15.3	2, 6, 10, 11
14	Jensen	Rat		9.2-14.4	10, 12-15
15	Rous	Chick	Ringer glucose	4.6-12.1	12, 16, 17
16			Serum	6.0	18
17	Tumor, ascites cells	Mouse	Krebs-Ringer phosphate	324[2]	19
18	Ehrlich ascites cells[3]			8.1	20
19	Spontaneous	Chick	Ringer glucose	7.3-8.8	1

/1/ µl oxygen consumed per mg wet weight. /2/ µl oxygen consumed per ml per hr. /3/ 5 x 10^7 cells per ml.

Contributors: (a) Vernberg, F. J., (b) Fitzgerald, L. R., (c) Barker, S. B., (d) Quastel, J. H., and Scholefield, P. G.

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Section 2: Benign, and Hyperplastic Tissues

	Tissue	Animal	Medium	Q_{O_2}	Reference
	(A)	(B)	(C)	(D)	(E)
1	Goiter, colloid, resting	Man	Ringer glucose	2.5-5.2	1, 2
2	Hyperactive			12.3	2
3	Heart, fibroblasts[1], 1 transfer	Chicken, young	Serum glucose	22.5	3
4	3-8 transfers			12.8	3
5	3000 transfers			12.0	3
6	Papilloma, bladder	Man	Ringer glucose	8.5-13.0	4
7	Polyp, nasal			4.2-5.9	4
8	Tonsil, hyperplastic			6.6-14.7	4
9	Wart, skin			1.5	5

/1/ In tissue culture.

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Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part VIII: NERVE TISSUES

Section 1: Central and Retinal

	Tissue (A)	Animal (B)	Medium (C)	Q_{O_2} (D)	Reference (E)
1	Brain	Man		3.31/1/	1
2		Rat	Ringer phosphate	5.4	2
3				3.3	3
4			Krebs-Ringer phosphate	1.30/2/	4
5			Krebs-Ringer phosphate, glucose (37°C)	25.03/1/	5
6			(42°C)	32.44/1/	5
7		Castrate, 30 da	Ringer phosphate	7.3	2
8		Chick embryo	Serum	25	6
9		Fish, Arctic cod	Ringer phosphate (25°C), mince	1.65/2/	7
10		Flounder	Phosphate buffer (30°C)	6.96/3/	8
11		Golden orfe	Ringer phosphate (25°C), mince	1.37/2/	7
12		Goldfish	Phosphate (27°C), brei	11.9/2/	9
13		Menhaden	Phosphate buffer (30°C)	13.04/3/	10
14		Mullet		13.52/3/	8
15		Pinfish		9.30/3/	8
16		Scup		10.51/3/	10
17		Spot		7.78/3/	8
18		Toadfish		6.78/3/	10
19	Cerebral cortex	Man	Ringer glucose	6.0-10.3	11
20			Ringer's solution	1.09/2/	12
21		Cat	Ringer glucose	8.5-12.2	11, 13
22		Dog		6.7	14
23		1 wk	Phosphate saline, glucose	2.44/4/	14, 15
24		3 wk		2.72/4/	14, 15
25		5-7 wk		4.84/4/	14, 15
26		Guinea pig	Saline	6.9	16
27			Saline glucose	11.7	17
28			Saline phosphate, glucose	530/5/	18
29			Phosphate buffer	53/6/	19
30			Saline, glucose, phosphate	620/5/	18
31		Monkey	Ringer glucose	7.4-11.8	11
32		Mouse	Ringer's solution	11.0	20
33		Pig, fetus 29-60 da		5.5	21
34		99 da		6.5	21
35		Birth to adult		8.5	21
36		Rabbit	Ringer glucose	7.3-10.4	22-24
37			Phosphate buffer	24.0/6/	19
38		Rat, 5 da	Ringer glucose	6.2	25
39		50 da		14.7	25
40		Adult		8.5-17.1	11,25-31
41			Krebs-Ringer phosphate	10.40	32
42			Krebs-Ringer phosphate, glucose	8.57	33
43			Saline, glucose, phosphate	570/5/	18
44		Pigeon	Saline glucose	14.6	17
45	Cerebellum	Dog, 1 wk	Phosphate saline, glucose	3.16/4/	14, 15
46		3 wk		3.48/4/	14, 15
47		5-7 wk		3.80/4/	14, 15
48		Adult		4.28/4/	14, 15
49	Hippocampus	Frog	Ringer's solution	2.4	34

/1/ ml oxygen consumed per 100 g brain per min. /2/ µl oxygen consumed per mg wet weight per hr. /3/ µl oxygen consumed per g wet weight per min. /4/ Converted to dry weight basis from author's data for fresh tissue. Since nerve tissue contains approximately 75% water, a per mg dry weight value was obtained by multiplying by 4. /5/ µl mol. oxygen consumed per g dry weight per hr. /6/ µM oxygen consumed per g wet weight per hr.

Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part VIII: NERVE TISSUES (Continued)

Section 1: Central and Retinal (Continued)

	Tissue (A)	Animal (B)	Medium (C)	Q_{O_2} (D)	Reference (E)
50	Medulla	Cat	Ringer glucose	3.5	13
51		Dog, 1 wk	Phosphate saline, glucose	3.84/4/	14,15
52		3 wk		4.12/4/	14,15
53		5-7 wk		3.40/4/	14,15
54		Adult		2.76/4/	14,15
55		Rat, 5 da	Ringer glucose	3.4	25
56		50 da		9.0	25
57		Adult		2.5-4.9	25,35
58	Thalamus	Dog, 1 wk	Phosphate saline, glucose	3.04/4/	14,15
59		3 wk		3.88/4/	14,15
60		5-7 wk		4.94/4/	14,15
61		Adult		4.04/4/	14,15
62	Hypothalamus	Rat	Ringer glucose	10.4	35
63	Anterior		Krebs-Ringer phosphate	7.53	36
64	Posterior			7.92	36
65	Spinal cord	Cat	Ringer glucose	1.3	13
66		1 wk	Phosphate saline, glucose	3.24/4/	14,15
67		3 wk		3.72/4/	14,15
68		Adult		2.00/4/	14,15
69		Frog	Ringer glucose	2.3	29
70	Retina	Dog		20.8	37
71		Frog		3.5	38
72		Ox		10.7	39
73		Pig		17.7	40
74		Sheep	Krebs-Ringer solution, glucose pH 5	0.74	41
75			pH 6	3.67	41
76			pH 7	7.47	41
77			pH 7.4	8.90	41
78		Rabbit	Ringer phosphate, glucose	10.9	42
79		Alloxan diabetes		8.7	42
80		Rat	Ringer glucose	22.0-32	22,31,38,40,43,44

/4/ Converted to dry weight basis from author's data for fresh tissue. Since fresh nerve tissue contains approximately 75% water, a per mg dry weight value was obtained by multiplying by 4.

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Section 2: Peripheral

Values for oxidation quotient (QO_2) are expressed in cu mm oxygen consumed per g fresh weight of tissue per hour. Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Tissue	Animal	Temp, °C	QO_2	Reference
	(A)	(B)	(C)	(D)	(E)
1	Axon, isolated giant	Cuttlefish (Sepia officinalis)	21	160	1
2	Single giant	Squid (Loligo pealii)	16	68[1] (47-86)	2
3	Cardiac, inferior	Cat	36	136 (96-182)	3
4	Cervical sympathetic	Rabbit	36	154 (114-265)	3
5	Intercostal	Cow	37	208[2] (154-240)	4
6	Lateral line	Dogfish (Mustelus canis)	22	75[3] (45-124)	5
7	Phrenic	Dog	38	140	6
8		Rat	36	151 (135-167)	3
9	Sciatic	Frog (Rana esculenta)	14.6	16[4] (11-21)	7
10		(R. pipiens)	21.5	42[5] (20-80)	8
11			22.0	37[6] (19-62)	9
12		(R. temporaria)	14.6	23[7] (17-27)	7
13			15.2	14.5[8] (12-19)	10
14		Dog	38	120.0[9]	8
15		Rabbit	37	288.0[10] (200-350)	11
16	Splanchnic	Cow	37	542[11] (369-669)	4
17	Stellar nerve trunk	Cuttlefish (Sepia officinalis)	21	74[12] (62-95)	1
18		Squid (Loligo pealii)	16	74[1]	2
19	Vagus	Dog	38	180 (135-195)	12
20	Ventral cord	Lobster (Homarus americanus)	24	123[13] (107-139)	13

/1/ Using oxygen electrode. /2/ In blood; reduced to 41 at 17°C. /3/ Corrected for temperature; mean R. Q., 0.83 (0.77-0.88). /4/ In winter; increased to 21 in spring; steady for 20 hr. /5/ Mostly in winter frogs; increased by half in summer; Q_{10} was 2.2. /6/ Figures calculated from Fenn's data by Gerard (1932); increased to 56 in summer. /7/ In winter; increased to 28 in spring; Q_{10}, 2.2. /8/ In winter. /9/ Reduced to 30 at 22°C; not altered if degenerated for a week. /10/ 235 in 2nd hr. /11/ In blood; not significantly different in Tyrode; slightly higher in calves; reduced to 68 at 17°C. /12/ In sea water. /13/ In sea water, decreases by 1.5% per hr.

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Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part IX: REPRODUCTIVE TISSUES

	Tissue (A)	Animal (B)	Medium (C)	Q_{O_2} (D)	Reference (E)
			Male		
1	Mammary gland	Rat, 15-25 wk	Ringer phosphate	3.4	1
2		>50 wk		1.9	1
3	Prostate		Ringer glucose	7.6	2
4			Krebs-Ringer phosphate	1.52[1]	3
5	Seminal vesicles	Guinea pig	Ringer's solution	4.6[2]	4
6			Ringer glucose	6.1	5
7	Castrate			2.8	5
8		Rat	Krebs-Ringer phosphate	0.77[1]	3
9				2.7	6
10	Spermatozoa	Bull	Ringer phosphate	6.6	7
11			Horse serum	11.2	8
12			Horse serum, glucose	12.8	8
13			Whole serum[3]	90	9
14			Whole serum[4]	180	9
15	Epididymal		Ringer phosphate	2.6	10
16		Guinea pig		8.0	8
17			Serum	18.4	8
18	Ejaculated	Rabbit	Ringer phosphate	4.4	11
19		Ram		9.0	11
20		Rat	Serum	7.7	12
21		Fowl		2.8	11
22	Testis	Rabbit	Ringer glucose	7.7	13
23		Rat		7.5-14.3	14-20
24			Serum	11.0	12
25			Ringer phosphate	2.5	21
			Female		
26	Mammary gland	Rat, virgin	Ringer, bicarbonate, glucose	20.0[2]	22
27		15-25 wk	Ringer phosphate	2.9	1
28		>50 wk		2.2	1
29		Normal	Ringer phosphate, glucose	3.7	23
30		Breeder	Ringer phosphate	4.0	1
31		Castrate	Ringer phosphate, glucose	3.9	23
32		Pregnant		10.2	23
33		Termination of pregnancy	Ringer glucose	1.3	24
34		Parturition	Ringer, bicarbonate, glucose	52[2]	22
35		Lactating	Ringer phosphate, glucose	10.1	23
36		4th da	Ringer, bicarbonate, glucose	100.0[2]	22
37		12th da		105.0[2]	22
38		15-22 da	Ringer glucose	10.0	24
39		24 da	Ringer, bicarbonate, glucose	70.0[2]	22
40		Weaning, 2 da after	Ringer glucose	5.5	24
41		7 da after	Ringer phosphate, glucose	5.1	23
42	Ovary	Mouse	Serum	9.0	12
43		Rat	Ringer glucose	5.7	2
44			Krebs-Ringer phosphate	1.14[1]	3
45	Uterus			0.73[1]	3
46				5.1	25
47		Castrate	Ringer glucose	5.3	25
48		Castrate	Ringer's solution	3.7	2
49		Castrate		5.2	25
50		Castrate, plus estrogen		7.9	25
51	Uterus, endometrium	Man, 1-5 da	Potassium pyruvate, glucose	1.97	26
52		6-10 da		3.49	26
53		18 da		2.68	26

/1/ cu mm oxygen consumed per mg wet weight per hr. /2/ μl oxygen consumed per mg nitrogen per hr. /3/ 10^9 sperm/ml. /4/ 2 x 10^9 sperm/ml. /5/ Micromoles oxygen per g wet weight per hr.

Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen consumed per mg dry weight of tissue per hour, unless otherwise indicated.

Part IX: REPRODUCTIVE TISSUES (Concluded)

	Tissue (A)	Animal (B)	Medium (C)	Q_{O_2} (D)	Reference (E)
	Female (concluded)				
54	Uterus, endometrium (concluded)	Man, menopausal	Potassium pyruvate, glucose	1.28	26
55			Saline solution, glucose	2.35	27
56	Proliferation, early		Krebs-Ringer glucose	3.24	28
57	Late			4.40	28
58	Secretory, early			3.87	28
59	Late			4.88	28

/5/ Micromoles oxygen per g wet weight per hr.

Contributors: (a) Vernberg, F. J., (b) Fitzgerald, L. R., (c) Barker, S. B., (d) Elliott, K. A., (e) Jandorf, B. J., (f) Quastel, J. H., and Scholefield, P. G.

References: [1] Tuba, J., and Fraser, M. S., Canad. J. M. Sc. 30:14, 1952. [2] Barker, S. B., and Schwartz, H. S., unpublished. [3] Barker, S. B., and Schwartz, H. S., Proc. Soc. Exp. Biol. 83:500, 1953. [4] Humphrey, G. F., and Robertson, M., Austral. J. Exp. Biol. 31:131, 1953. [5] Levey, H. A., and Szego, C. M., unpublished. [6] Porter, J. C., and Melampy, R. M., Endocrinology 51:412, 1952. [7] Lardy, H. A., and Phillips, P. H., J. Biol. Chem. 148:333, 1943. [8] Redenz, E., Biochem. Zschr. 257:234, 1933. [9] Bishop, M. W., and Salisbury, G. W., Am. J. Physiol. 180:107, 1955. [10] Lardy, H. A., Hansen, R. G., and Phillips, P. H., Arch. Biochem., N. Y. 6:41, 1945. [11] Lardy, H. A., and Phillips, P. H., Am. J. Physiol. 138:741, 1943. [12] Fujita, A., Biochem. Zschr. 197:175, 1928. [13] Ebina, T., Tohoku J. Exp. M. 13:424, 1929. [14] Barker, S. B., and Klitgaard, H. M., Am. J. Physiol. 170:81, 1952. [15] Dickens, F., and Greville, G. D., Biochem. J., Lond. 27:832, 1933. [16] Dickens, F., and Simer, F., ibid 35:7, 1941. [17] Edson, N. L., and Leloir, L. F., ibid 30:2319, 1936. [18] Elliott, K. A., Greig, M. E., and Benoy, M. P., ibid 31:1003, 1937. [19] Warburg, O., Posener, K., and Negelein, E., Biochem. Zschr. 152:309, 1924. [20] Weil-Malherbe, H., Biochem. J., Lond. 32:2257, 1938. [21] Paul. H. E., Paul, M. F., and Kopko, F., Proc. Soc. Exp. Biol. 79:555, 1952. [22] Hoover, C. R., and Turner, C. W., Endocrinology 54:666, 1954. [23] Tuba, J., Rawlinson, H. E., and Shaw, L. G., Canad. J. Res. 28:217, 1950. [24] Folley, S. J., and French, T. H., Biochem. J., Lond. 45:270, 1949. [25] Roberts, S., and Szego, C. M., J. Biol. Chem. 201:21, 1953. [26] Hagerman, D. D., and Villee, C. A., Endocrinology 53:667, 1953. [27] Hagerman, D. D., and Villee, C. A., J. Biol. Chem. 203:425, 1953. [28] Stuermer, V. M., and Stein, R. J., Am. J. Obst. 63:359, 1952.

Part X: PLACENTAL TISSUES

	Tissue (A)	Animal (B)	Medium (C)	Q_{O_2} (D)	Reference (E)
1	Allantois	Chick	Ringer glucose	22.3	1
2	Chorio-allantois			10.4	2
3	Chorio-allantois and yolk sac		Krebs saline phosphate	5.6	3
4	Chorion	Rat	Ringer glucose	13.5	1
5	Decidua	Man	Serum	2.5	4
6	Placenta, 7 wk	Man	Salt solution, pyruvate, glucose	3.1	5
7	15 wk			2.8	5
8	30 wk			2.2	5
9	0.4 mg	Mouse	Serum	7.5	6
10	10.9-13.7 mg			6.4	6
11	Fetal side	Rabbit		5.3	4
12	Uterine side			3.4	4
13		Rat	Horse serum	3.9	4
14	20 da		Ringer's solution	7.3	7

Contributors: (a) Vernberg, F. J., (b) Fitzgerald, L. R., (c) Barker, S. B., (d) Elliott, K. A., (e) Quastel, J. H., and Scholefield, P. G.

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Values presented in these tables should be considered representative, but not exact, as rarely are enough data presented to justify statistical treatment, and rarely is independent confirmatory information available. Unless otherwise specified, values are for a single, intact embryo.

Part I: SHEEP

Based on blood-flow and blood-gas analysis.

	Age, da (A)	Wet Weight, g (B)	µl O_2/hr (C)	µl O_2/g/hr (D)		Age, da (A)	Wet Weight, g (B)	µl O_2/hr (C)	µl O_2/g/hr (D)
1	78	250	120,000	474	10	127	2850	672,000	234
2	95	570	426,000	750	11	129	2750	1,512,000	486[1]
3	99	920	378,000	408	12	130	2850	726,000	252
4	106	960	552,000	576	13	136	2810	864,000	396
5	108	1050	498,000	474	14	137	3850	1,200,000	312
6	111	1200	276,000	228	15	138	3650	930,000	252
7	112	1000	252,000	252	16	141	4100	1,320,000	324
8	123	2040	558,000	234	17	144	3500	840,000	240
9	126	3000	738,000	246	18	152	2800	984,000	258

/1/ The author believes this value too high, but cannot define the source of error.

Contributor: Fitzgerald, L. R.

Reference: Barcroft, J., "Researches on Prenatal Life," Springfield, Ill.: Charles C. Thomas, 1947.

Part II: RAT

In Lines 1-10, values are based on Cartesian Diver technique; with the exception of Lines 37 and 39, values in Lines 11-44 are based on Warburg manometric technique. Medium: A = 0.8% NaCl, phosphate buffer, pH 7.4; B = serum + 0.025 M bicarbonate buffer + 0.2% glucose; C = serum + 0.025 M bicarbonate buffer + 0.011 M glucose; D = Krebs solution; E = Ringer-phosphate, pH 7.4.

	Age da (A)	Stage (B)	Medium (C)	Dry Weight mg (D)	µl O_2/hr (E)	Q_{O_2}[1] (F)	$Q_M^{O_2}$[2] (G)	$Q_M^{N_2}$[3] (H)	QS[4] (I)	R.Q. (J)	Reference (K)
1		Follicular ovum	A		0.00111	29					1
2		1 cell	A		0.00072	29					1
3		2 cells	A		0.00072	29					1
4		2-4 cells	A		0.00073	29					1
5		3-4 cells	A		0.00080	32					1
6		8 cells	A		0.00106	42.5					1
7		8-16 cells	A		0.00094	38					1
8		1-16 cells	A	0.0002	0.00073						2
9	8		A		0.01	19.5					2
10	10		A		0.2	13.5					2
11			B	0.11			12.8				3
12			B	0.36				18.0			3
13			B	0.39				26.3			3
14			B	0.46			15.9				3
15			B	0.47				32.0			3
16			B	0.57				27.3			3
17			B	0.67			8.2				3
18			B	0.90[5]	12	13.3			13.2		3
19			B	0.90[6]	10.5	11.8			15.0		3
20			B	1.00[5]	14.6	14.6			15.8		3
21			B	1.00[6]	13.6	13.6			17.8		3
22			B	1.10[5]	11.7	10.6			9.2		3
23			B	1.10[6]	11.6	10.6			11.0		3
24			C	1.34				26			4
25			C	1.68				20			4
26			B	1.87				14.5			3
27			B	1.88				16.8			3
28			B	2.40	36.7	14.3	6.7				3
29			B	2.48				15.1			3
30			B	2.50			0				3
31			B	2.55			0				2
32			B	2.62				10.0			3

/1/ Q_{O_2} = cu mm O_2 consumed per mg dry weight tissue per hr. /2/ $Q_M^{O_2}$ = cu mm lactic acid formed in O_2 per mg dry weight tissue per hr. /3/ $Q_M^{N_2}$ = cu mm lactic acid formed in N_2 per mg dry weight tissue per hr. /4/ QS = cu mm acid (carbonic + lactic) formed per mg dry weight tissue per hr. /5/ Membranes intact. /6/ Membranes destroyed.

Part II: RAT (Concluded)

With the exception of Lines 37 and 39, values in Lines 11-44 are based on Warburg manometric technique. Medium: A = 0.8% NaCl, phosphate buffer, pH 7.4; B = serum + 0.025 M bicarbonate buffer + 0.2% glucose; C = serum + 0.025 M bicarbonate buffer + 0.011 M glucose; D = Krebs solution; E = Ringer-phosphate, pH 7.4.

	Age da	Stage	Medium	Dry Weight mg	µl O_2/hr	Q_{O_2}[1]	$Q_M^{O_2}$[2]	$Q_M^{N_2}$[3]	QS[4]	R.Q.	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
33			B	3.10[5]	38.7	12.5			12.2		3
34			B	3.10[6]	41.2	13.3			14.4		3
35			B	4.75				9.5			3
36			B	4.89				10.7			3
37	12		D		47						5
38	13		E	8.0	55	7.2					6
39	13		D		65						5
40			E	10.0						1.04	7
41			B	10.6				7.5			3
42			E	30						1.04	7
43	13-14		E			9	0.5	2		0.7-1.0	8
44	13-14		E[7]			11		12		1.00	8
45	14		D		145						5
46	15		D		113						5
47	16		D		154						5

/1/ Q_{O_2} = cu mm O_2 consumed per mg dry weight tissue per hr. /2/ $Q_M^{O_2}$ = cu mm lactic acid formed in O_2 per mg dry weight tissue per hr. /3/ $Q_M^{N_2}$ = cu mm lactic acid formed in N_2 per mg dry weight tissue per hr. /4/ QS = cu mm acid (carbonic + lactic) formed per mg dry weight tissue per hr. /5/ Membranes intact. /6/ Membranes destroyed. /7/ Medium contained added glucose.

Contributor: Fitzgerald, L. R.

References: [1] Boell, E. J., and Nicholas, J. S., J. Exp. Zool. 109:267, 1948. [2] Boell, E. J., and Nicholas J. S., Science 90:411, 1939. [3] Negelein, E., "The Metabolism of Tumors," (ed. Warburg, O.,), London: Constable, 1930. [4] Kuomanomido, S., Biochem. Zschr. 193:315, 1928. [5] Mislivechkova, A., Cesk. Morfol. 2:118, 1954. [6] Kleiber, M., Cole, H. H., and Smith, A. H., J. Cellul. Physiol. 22:167, 1943. [7] Dickens, F., and Simer, F., Biochem. J., Lond. 24:1301, 1930. [8] Dickens, F., and Greville, G. D., ibid 27:832, 1933.

Part III: GUINEA PIG

Values derived from blood-flow and blood-gas measurements.

	Wet Weight, g	µl O_2/hr	µl O_2/g/hr	µl CO_2/hr	µl CO_2/g/hr	R.Q.
	(A)	(B)	(C)	(D)	(E)	(F)
1	5.5	4,500	810	7,500	1,350	1.67
2	16	12,000	756	12,000	756	1.00
3	23.8	6,000	252	6,000	252	1.00
4	35.8	23,000	643	21,000	586	0.91
5	39	15,000	385	18,000	462	1.20
6	61.5	27,000	440	30,000	488	1.11

Contributor: Fitzgerald, L. R.

Reference: Bohr, C., Skand. Arch. Physiol., Berl. 10:413, 1900.

Part IV: CHICK

Section 1

Warburg manometric procedures on isolated embryos. Manometric determinations on intact embryos followed by extensive calculations based on separate studies of membrane growth and respiration [1]. Medium: A = intact egg in air; B = intact egg in air and isolated tissues in Ringer-phosphate, pH 7.4; C = isolated embryo in Ringer-phosphate, pH 7.2; D = isolated embryo in Krebs solution + 0.24% glucose; E= isolated embryo in Ringer-phosphate, pH 7.4; F = isolated embryo in Ringer-phosphate or Ringer-bicarbonate, pH 7.4. Where values are enclosed in parentheses, glucose was added to the medium.

	Age	Medium	Wet Weight mg	µl O_2/hr	µl O_2/g/hr	Q_{O_2}	µl CO_2/hr	µl CO_2/g/hr	R.Q.	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	15 hr	C				14.0				2
2	16 hr	C		4.75(7.12)						2
3	16 1/4 hr	C		4.73(5.57)						2
4	24 hr	C				12.9				2
5	25 1/4 hr	C		6.91(8.32)						2
6	48 hr	C		14.5(19.0)		10.7				2

Part IV: CHICK (Continued)

Section 1 (Concluded)

Warburg manometric procedures on isolated embryos. Manometric determinations on intact embryos followed by extensive calculations based on separate studies of membrane growth and respiration [1]. Medium: A = intact egg in air; B = intact egg in air and isolated tissues in Ringer-phosphate, pH 7.4; C = isolated embryo in Ringer-phosphate, pH 7.2; D = isolated embryo in Krebs solution + 0.24% glucose; E = isolated embryo in Ringer-phosphate, pH 7.4; F = isolated embryo in Ringer-phosphate or Ringer-bicarbonate, pH 7.4. Where values are enclosed in parentheses, glucose was added to the medium.

	Age	Medium	Wet Weight mg	µl O_2/hr	µl O_2/g/hr	Q_{O_2}	µl CO_2/hr	µl CO_2/g/hr	R.Q.	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
7	72 1/2 hr	C		24.1(27.4)		10.7				2
8	4 da					16.5				3
9		A				10.0				4
10		D				13.3			0.99-1.05	5
11	5 da	A				10.5[1]				4
12		E							1.00	6
13		F				8.3(10.0)			0.89(1.00)	7
14						10.9				3
15	6 hr-5 da	B							0.95-1.00	8
16	6 da	B	562	595	1226					1
17		A	428				528	1200		9, 10
18		A				10.2				4
19	7 da	A	832				1000	1250		9, 10
20		B	901	869	1076					1
21						9.4				3
22	8 da	B	1488	1357	1021					1
23		A	1015				1180	1190		9, 10
24						7.5				3
25	9 da	B	2068	2090	1050					1
26		B	1633				2025	1240		8
27	10 da	B	3168	2719	949					1
28		A	2534				2920	1160		9, 10
29	11 da	B	4304	4050	1015					1
30		A	3577				4080	1135		9, 10
31	12 da	B	6100	5460	992					1
32		A	4612				5375	1155		9, 10
33	13 da	B	8555	8262	1055					1
34		A	8629				8900	1030		9, 10
35	14 da	B	11,838	10,783	1023					1
36		A	11,431				10,500	920		9, 10
37	15 da	B	14,320	13,293	1030					1
38		A	14,862				13,400	900		9, 10
39	16 da	B	17,570	15,600	990					1
40		A	16,387				14,000	900		9, 10
41	17 da	B	21,870	18,450	920					1
42		A	20,312				15,300	755		9, 10
43	18 da	B	24,210	19,100	850					1
44		A	24,044				15,100	660		9, 10
45	19 da	B	28,270	20,900	765					1
46		A	25,218				15,300	610		9, 10

/1/ When serum instead of Ringer's solution was used in medium, Q_{O_2} = 12.9.

Contributors: (a) Fitzgerald, L. R., (b) Moog, F.

References: [1] Needham, J., Proc. Roy. Soc., Lond., B 110:46, 1932. [2] Philips, F. S., J. Exp. Zool. 86:257, 1941. [3] Kayser, C., Le Breton, E., and Schaffer, G., C. rend. Acad. sc. 181:255, 1925. [4] Romanoff, A. L., J. Cellul. Physiol. 18:199, 1941. [5] Elliott, K. A., and Baker, Z., Biochem. J., Lond. 29:2433, 1935. [6] Dickens, F., and Simer, F., ibid 24:1301, 1930. [7] Dickens, F., and Greville, G. D., ibid 27:832, 1933. [8] Needham, J., Proc. Roy. Soc., Lond., B 112:98, 1932. [9] Murray, H. A., Jr., J. Gen. Physiol. 9:1, 1925-26. [10] Murray, H. A., Jr., ibid 10:337, 1926-27.

152. O_2 CONSUMPTION: FETAL TISSUES (Continued)
Part IV: CHICK (Concluded)
Section 2

Method based on Warburg manometric technique. Medium was serum; where values are enclosed in parentheses, however, the medium used was Ringer's solution.

	Dry Weight mg	Q_{O_2} [1]	$Q_M^{O_2}$ [2]	$Q_M^{N_2}$ [3]		Dry Weight mg	Q_{O_2} [1]	$Q_M^{O_2}$ [2]	$Q_M^{N_2}$ [3]
	(A)	(B)	(C)	(D)		(A)	(B)	(C)	(D)
1	0.085	16.4	5.9	25.8	29	2.13			13.7
2	0.086	18.1	9.2	29.4	30	2.15			9.1
3	0.093	20.2	7.5	23.6	31	2.21			8.8
4	0.10	16.4	7.9	25.5	32	2.40	11.6	0.85	13.3
5	0.27	22.4	5.5	18.5	33	2.44			19.3
6	0.54	15.2	4.5	16.0	34	2.64			(15.4)
7	0.58			12.9	35	2.67	12.9	0	10.5
8	0.70			(22.8)	36	2.86			(17.0)
9	0.79			(22.8)	37	2.89			9.4
10	0.81			(22.9)	38	2.91			14.7
11	0.83			12.9	39	2.98			11.4
12	0.86			14.8	40	3.02			(17.4)
13	0.905	14.3	0.6	11.4	41	3.08[4]	11.6[5]	3.2	
14	0.92			(15.4)	42	3.19			(17.9)
15	0.95	15.9	6.9	21.0	43	3.24			9.5
16	0.97			(25.9)	44	3.27			(14.5)
17	1.01	18.9	1.7	11.5	45	3.49			8.8
18	1.02			(18.8)	46	3.52			(18.8)
19	1.16	20.2	3.8	13.1	47	3.57			12.4
20	1.17			15.1	48	3.87	10.5	0.95	9.7
21	1.20	21.4	5.1	16.3	49	3.97			(13.8)
22	1.23			(20.8)	50	4.01			(13.3)
23	1.29			12.5	51	4.10[4]	11.3[6]	1.3	
24	1.32			15.6	52	4.21			(15.2)
25	1.67			(21.4)	53	4.27			(18.5)
26	1.86	16.4	0.9	9.7	54	4.35			9.7
27	1.90			(24.0)	55	4.73	8.1	1.2	7.5
28	1.92			15.4	56	5.03			5.0

/1/ Q_{O_2} = cu mm O_2 consumed per mg dry weight tissue per hr. /2/ $Q_M^{O_2}$ = cu mm lactic acid formed in O_2 per mg dry weight tissue per hr. /3/ $Q_M^{N_2}$ = cu mm lactic acid formed in N_2 per mg dry weight tissue per hr. /4/ Data are from Reference [2]. /5/ R.Q. = 0.99. /6/ R.Q. = 0.98.

Contributor: Fitzgerald, L. R.

References: [1] Kuomanomido, S., Biochem. Zschr. 193:315, 1928. [2] Dickens, F., and Simer, F., Biochem. J., Lond. 25:985, 1931.

Part V: BLACK SNAKE (*Coluber constrictor*)

Method based on Warburg manometric technique at 23.9°C.

	Age, da	µl O_2/g/hr	µl O_2/hr	µl CO_2/hr	R.Q.		Age, da	µl O_2/g/hr	µl O_2/hr	µl CO_2/hr	R.Q.
	(A)	(B)	(C)	(D)	(E)		(A)	(B)	(C)	(D)	(E)
1	1	3500	210	159	0.76	24	30		337	173	0.51
2	2		162			25	31	200	356	204	0.57
3	3	1610	185	161	0.87	26	33		334	177	0.53
4	4		120			27	34	192	350	183	0.52
5	5		135			28	36		365	176	0.48
6	6		225	181	0.81	29	38		378	229	0.61
7	7		194	99	0.51	30	39		426	235	0.55
8	8	635	198			31	41		478	279	0.58
9	9		236			32	43	177	500	290	0.58
10	10		223			33	44		552	313	0.57
11	12	468	305			34	46		531	271	0.52
12	13		282			35	48		575	326	0.57
13	15		162			36	50		722	380	0.53
14	17		234			37	51	175	656	357	0.54
15	18	310	272			38	53		813	428	0.54
16	20		253			39	55		873	490	0.56
17	22		256			40	56		970	530	0.55
18	23		252	126	0.50	41	58	175	962	560	0.58
19	24	233	277			42	59		1021	476	0.47
20	25		300	154	0.51	43	61		1021	561	0.55
21	26		282	123	0.44	44	62	175	1227	550	0.45
22	27	226	334			45	64		1080	583	0.54
23	28		318	166	0.52	46	67	125	1026	565	0.55

Contributor: Clark, H.

Reference: Clark, H., J. Exp. Biol., Lond. 30:502, 1953.

Part VI: FROG (Rana fusca)

Medium: aquarium water.

	Age, hr	Stage	µl O_2/hr	R.Q.	mg Lactic Acid/100 ova/hr		Reference
					Aerobic	Anaerobic	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1		Unfertilized ova			0	0.04	1
2	1		0.093				2
3		Fertilized ova[1]			0	0.05	1
4	2		0.126				2
5	3-4		0.164				2
6		2 blastomeres		0.72			1
7		Morula	0.098-0.120	0.65			1
8	16-20	Blastula	0.151				2
9		Blastula	0.146	0.70			1
10		Gastrula	0.184-0.213	1.03	0.045	0.079	1
11		Neurula	0.334	0.98	0.057	0.069	1
12		Tadpole	1.167	0.97			1

/1/ Cleavage?

Contributor: Fitzgerald, L. R.

References: [1] Brachet, J., Arch. Biol., Par. 45:611, 1934. [2] Brachet, J., ibid 46:1, 1935.

Part VII: FROG (Rana temporaria)

Minced embryos in Ringer-bicarbonate.

	Tadpole	$Q_M^{N_2}$
	(A)	(B)
1	8-10 mm	19.35
2	10-12 mm	12.7
3	12-14 mm	12.1
4	16-18 mm	10.72
5	18-20 mm	11.9
6	20-22 mm	14.6

Contributor: Fitzgerald, L. R.

Reference: Nowinski, W. W., Biochem. J., Lond. 33:978, 1939.

Part VIII: GRASS OR LEOPARD FROG (Rana pipiens)

Section 1: Fertilized Ova[1]

Medium: spring water or 10% Ringer's solution.

	After Fertilization, hr	µl O_2/hr
	(A)	(B)
1	2 1/2-3 1/2	0.050
2	2 3/4-3 3/4	0.054
3	3-4	0.054
4	3 1/4-4 1/4	0.055
5	3 1/2-4 1/2	0.059
6	4-5	0.052
7	5-6	0.061
8	6-7	0.057
9	6 1/2-7 1/2	0.058

/1/ Extensive data for later stages given in graphic form in the reference.

Contributors: (a) Fitzgerald, L. R., (b) Moog, F.

Reference: Atlas, M., Physiol. Zool. 11:278, 1938.

Part VIII: GRASS OR LEOPARD FROG (Rana pipiens) (Concluded)

Section 2: Shumway Development Stages

Medium: aquarium water.

	Stage	Description	µl O_2/hr	R.Q.
	(A)	(B)	(C)	(D)
1	3	Cleavage, early	0.052	
2	3	2 cells	0.049-0.056	0.73-1.05
3	6+	16-32 cells	0.080	0.88
4	7+	Cleavage	0.105	0.84-0.88
5	10	Gastrula, beginning	0.173	0.90-0.93
6	10+		0.136	0.90
7	11+	Middle	0.147	0.87
8	12	Late	0.195-0.250	0.82-0.87
9	13	Neural plate	0.220-0.320	0.82-0.87
10	14	Neural fold	0.240-0.270	0.83-0.84
11	15	Neurula	0.280-0.290	0.81-0.86
12	16+	Gill-plate	0.330-0.490	0.81-0.88

Contributor: Fitzgerald, L., R.
Reference: Barth, L. G., J. Exp. Zool. 103:463, 1946.

Section 3: Harrison Development Stages

Method based on Warburg manometric techniques. Medium: aquarium water.

	Age, da	Stage	µl O_2/hr		Age, da	Stage	µl O_2/hr
	(A)	(B)	(C)		(A)	(B)	(C)
1	0	0	0.06	41	29		23.49
2	1	1	0.08	42	30		18.40
3	1	1	0.10	43	31		19.94
4	1	2-3	0.07	44	32		21.75
5	1	3	0.12	45	33		18.09
6	1	4-5	0.06	46	34		17.34
7	1	5-6	0.10	47	35		17.22
8	1	7	0.08	48	36		19.99
9	1	7-8	0.09	49	37		19.81
10	1	8	0.23	50	38		19.12
11	1	10	0.39	51	39		18.85
12	2	11	0.56	52	40		18.18
13	2	12-13	0.70	53	41		22.49
14	2	18-19	0.88	54	42		20.72
15	3	25-28	0.98	55	43		18.58
16	3	29-33 (Hatching)	1.22	56	44		25.00
17	3	35	1.61	57	45		18.13
18	4	37	1.93	58	47		22.99
19	5	Feeding begins	3.26	59	48		27.13
20	6		4.49	60	49		25.09
21	7		7.27	61	50		35.46
22	8		6.95	62	51		27.29
23	9		5.83	63	52		32.57
24	10		4.59	64	53		31.10
25	11		4.64	65	54		41.15
26	12		5.03	66	55		34.25
27	13		4.33	67	60		43.8
28	14		6.27	68	67		52.2
29	15		5.92	69	72		63.1
30	17		6.34	70	73		38.1
31	18		7.52	71	74		115.6
32	19		7.85	72	78		85.4
33	20		12.04	73	81		192.8
34	21		12.23	74	83		79.0
35	22		12.02	75	85		69.6
36	23		14.21	76	86		85.3
37	24		13.96	77	90	Metamorphosis	95.2
38	26		14.73	78	100	Metamorphosis	127.4
39	27		18.31	79	110		176.1
40	28		16.98				

Contributor: Fitzgerald, L. R.
Reference: Wills, I. A., J. Exp. Zool. 73:481, 1936.

Part IX: PACIFIC COAST NEWT, OR "WATER DOG" (*Triturus torosus*)

Medium: aquarium water. Stages refer to the Harrison stage of comparable development.

	Age, da	Stage	µl O_2/hr		Age, da	Stage	µl O_2/hr
	(A)	(B)	(C)		(A)	(B)	(C)
1	1	1-3	0.49	18	20	39 (Hatching)	2.40
2	1	3-6	0.25	19	21	40	2.39
3	2	7-8	0.20	20	24	43	2.90
4	3	9	0.39	21	25	44 (Feeding begins)	3.40
5	3	10	0.31	22	30		3.23
6	3	11	0.46	23	55		43.79
7	3	12	0.39	24	65		21.38
8	5	15	0.43	25	75		53.27
9	5	17	0.60	26	90		56.31
10	5	19	0.54	27	95	Metamorphosis	52.30
11	5	20	0.67	28	100	Metamorphosis	72.24
12	6	22	0.57	29	105	Metamorphosis	68.52
13	7	23	0.68	30	110	Metamorphosis	91.65
14	9	29	0.44	31	115		57.62
15	14	35	1.04	32	120		60.90
16	18	37	1.20	33	135		60.30
17	19	38	1.49				

Contributor: Fitzgerald, L. R.

Reference: Wills, I. A., J. Exp. Zool. 73:481, 1936.

Part X: SPOTTED AND TIGER SALAMANDERS (*Amblystoma punctatum*, *A. tigrinum*)

Method based on modified Thunberg differential respirometer. Medium: either tap water or spring water. Stages refer to the Harrison stage of comparable development.

	Stage	A. punctatum			A. tigrinum		
		Dry Weight, mg	µl O_2/hr	Q_{O_2}	Dry Weight, mg	µl O_2/hr	Q_{O_2}
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	7,8,9	2.67	0.180	0.0677			
2	10	3.18[1]	0.265[1]	0.0838[1]	2.48	0.393	0.1586
3	11				2.93	0.491	0.1676
4	12	2.86	0.283	0.0990	2.93	0.516	0.1762
5	13				2.25	0.464	0.2062
6	14	2.97	0.343	0.1156	2.90	0.661	0.2280
7	15	2.81	0.342	0.1219			
8	16	3.08	0.392	0.1275	2.60	0.591	0.2274
9	17	2.63	0.362	0.1378			
10	18	3.28	0.430	0.1313	3.28	0.692	0.2264
11	19	3.26	0.490	0.1505			
12	20	2.13	0.343	0.1611	1.97	0.471	0.2395
13	21	3.08	0.482	0.1565			
14	22				2.23	0.627	0.2815
15	23	3.01	0.482	0.1602			
16	24	2.93	0.472	0.1611	2.03	0.685	0.3377
17	25	3.28	0.553	0.1689			
18	26				2.72	0.907	0.3334
19	27	2.99	0.622	0.2080			
20	28	2.18	0.491	0.2257	2.83	0.964	0.3406
21	29						
22	30	3.30	0.885	0.2681	2.56	0.961	0.3754
23	31	3.02	0.911	0.3023			
24	32				2.85	1.285	0.4510
25	33	3.31	0.947	0.3126			
26	34				2.82	1.316	0.4668
27	35	2.99	1.070	0.3579			
28	36				2.62	1.366	0.5218
29	37	3.19	1.553	0.4868	2.19	1.313	0.5999
30	38				2.82	2.605	0.9240
31	39	2.30	1.883	0.8186	2.31	2.319	1.004
32	40	2.47	2.458	0.9950	2.49	2.585	1.038
33	41	2.31	3.710	1.616			
34	42				1.78	2.389	1.335
35	43	2.27	3.705	1.632	1.78	3.262	1.833
36	44				1.43	4.058	2.838
37	45	1.80	2.742	1.524	2.74	9.113	3.326
38	46				1.43	3.167	2.215
39	14-16 mm larva	2.24	3.516	1.556			
40	14-21 mm larva				2.20	4.974	2.231

/1/ Average for more than one weight of embryo.

Part X: SPOTTED AND TIGER SALAMANDERS (Amblystoma punctatum, A. tigrinum) (Concluded)

Method based on modified Thunberg differential respirometer. Medium: either tap water or spring water. Stages refer to the Harrison stage of comparable development.

	Stage	A. punctatum			A. tigrinum		
		Dry Weight, mg	µl O_2/hr	QO_2	Dry Weight, mg	µl O_2/hr	QO_2
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
41	17-21 mm larva	4.38	6.597	1.542			
42	22-27 mm larva	7.80	9.422	1.225			
43	22-37 mm larva				15.81	28.86	1.919
44	28-36 mm larva	26.01	26.33	1.067			
45	37-48 mm larva	70.29	59.62	0.885			
46	38-54 mm larva				53.40	67.37	1.258
47	55-72 mm larva				148.3	136.4	0.936
48	73-93 mm larva				317.6	213.8	0.6784
49	82-85 mm larva				346.6	298.3	0.862

Contributor: Fitzgerald, L. R.

Reference: Hopkins, H. S., and Handford, S. W., J. Exp. Zool. 93:403, 1943.

Part XI: SPOTTED SALAMANDER (Amblystoma maculatum)

Method based on Warburg manometric technique. Medium: aquarium water. Stages refer to the Harrison stage of comparable development.

	Age, da	Stage	µl O_2/hr		Age, da	Stage	µl O_2/hr
	(A)	(B)	(C)		(A)	(B)	(C)
1	1	7-8	0.54	29	29		8.27
2	1	8-9	0.34	30	30		9.41
3	2	15-16	0.43	31	31		10.48
4	3	18-19	0.55	32	32		11.42
5	3-4	29-31	0.65	33	33		11.15
6	4	32	0.73	34	34		12.52
7	5	33-34	1.28	35	35		13.46
8	6	37-38	1.70	36	36		12.88
9	7	39-40	2.11	37	37		13.40
10	8	41	2.36	38	38		13.20
11	9	42 (Hatching)	2.69	39	39		15.36
12	10	43	3.64	40	40		17.19
13	11	44	4.53	41	41		18.22
14	12	45	5.46	42	42		18.98
15	14	46 (Feeding begins)	6.03	43	43		19.18
16	15	46	6.10	44	44		18.20
17	17		5.47	45	45		20.82
18	18		5.80	46	53		38.30
19	19		6.10	47	58		41.50
20	20		6.48	48	60		64.00
21	21		5.65	49	66		45.20
22	22		5.97	50	68		28.00
23	23		5.88	51	73		63.10
24	24		6.21	52	80		107.40
25	25		6.48	53	85	Metamorphosis	118.70
26	26		6.57	54	105		107.30
27	27		7.08	55	115		118.20
28	28		7.55				

Contributor: Fitzgerald, L. R.

Reference: Wills, I. A., J. Exp. Zool. 73:481, 1936.

Part XII: MEXICAN SALAMANDER (Amblystoma mexicanum)

Method based on Warburg manometric technique at temperature of 22.6°C.

	Age, hr	Stage	µl O_2/hr		Age, hr	Stage	µl O_2/hr
	(A)	(B)	(C)		(A)	(B)	(C)
1	8	Blastula	0.168	9	75		0.550
2	16	Gastrula, early	0.193	10	90		0.818
3	24	Gastrula, late	0.248	11	100		0.970
4	32	Neurula, early	0.286	12	115		1.365
5	40	Neurula, late	0.305	13	140		2.10
6	48	Tail-bud, early	0.325	14	165		2.71
7	56	Tail-bud, late	0.363	15	190		3.30
8	65		0.425	16	220		3.95

Contributor: Fitzgerald, L. R.

Reference: Fisher, F. G., and Hartwig, H., Biol. Zbl. 58:567, 1938.

Part XIII: ATLANTIC SALMON (Salmo salar)
Values are expressed in µl O_2/g wet wt/hr.
Medium: 10% sea-water.

	Age, da	Q_{O_2}
	(A)	(B)
1	19	136.5
2	21	137.5
3	24	131.5
4	26	136.5
5	30	151.0
6	32	146.0
7	35	156.0
8	37	137.0
9	39	149.0
10	45	145.0
11	50	152.0

Contributor: Fitzgerald, L. R.
Reference: Hayes, F. A., Wilmot, I. R., and Livingstone, D. A., J. Exp. Zool. 116:377, 1951.

Part XIV: COMMON KILLIFISH (Fundulus heteroclitus)
Medium: S-W = sea water; A = water-saturated air.

	Age	Stage	Medium	µl O_2/hr	µl CO_2/hr	R.Q.	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	1-1½ hr		S-W	0.029-0.036			1
2	1½-2 hr		S-W	0.026-0.033			1
3	2-2½ hr		S-W	0.023-0.037			1
4	2½-3 hr		S-W	0.022-0.035			1
5	2-5 hr	Up to 8 cells	S-W	0.01			2
6	3-3½ hr		S-W	0.028-0.038			1
7	3½-4 hr		S-W	0.025-0.037			1
8	4-4½ hr		S-W	0.022-0.044			1
9	4½-5 hr		S-W	0.027-0.054			1
10	5-5½ hr		S-W	0.026-0.040			1
11	4-6 hr	2-4 cells	S-W	0.04			2
12	6-8 hr	32 cells	S-W	0.03			2
13	9-11 hr	Small disc	S-W	0.02			2
14	9-11 hr	Many cells	S-W	0.04			2
15	22-24 hr	Large disc	S-W	0.05			2
16	1 da		A	0.03	0.03	0.85	3
17	26-29 hr		S-W	0.06			2
18	30-32 hr		S-W	0.07			2
19	34-37 hr	Embryo with eyes	S-W	0.07			2
20	2 da		S-W	0.07			2
21	2 da		A	0.09	0.07	0.77	3
22	2½ da		S-W	0.07			2
23	3 da		S-W	0.05			2
24	3 da		A	0.16	0.12	0.75	3
25	3½ da	Circulation established	S-W	0.12			2
26	4 da		A	0.21	0.16	0.75	3
27	4 da		S-W	0.09			2
28	4½ da		S-W	0.09			2
29	5 da		A	0.20	0.15	0.74	3
30	5½ da		S-W	0.08			2
31	6 da		A	0.26	0.19	0.74	3
32	6 da		S-W	0.07			2
33	7 da		A	0.35	0.25	0.70	3
34	8 da		A	0.40	0.28	0.70	3
35	9 da		A	0.48	0.35	0.74	3
36	10 da		A	0.43	0.32	0.76	3
37	11 da		A	0.41	0.30	0.73	3
38	12 da	Hatching begins	A	0.44	0.33	0.76	3

Contributor: Fitzgerald, L. R.
References: [1] Philips, F. S., Biol. Bull. 78:256, 1940. [2] Hyman, L. H., ibid 40:32, 1921. [3] Amberson, W. R., and Armstrong, P. B., J. Cellul. Physiol. 2:381, 1933.

153. EFFECT OF POTASSIUM ION CONCENTRATION ON O_2 CONSUMPTION: ANIMAL TISSUES

Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen per mg final dry weight of tissue per hour, unless otherwise indicated. Media are described in the appropriate footnotes in terms of quantity of ion per liter of solution.

Part I: GUINEA PIG LIVER AND RABBIT KIDNEY CORTEX

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	K^+ Concentration in Suspending Medium[1] mEq/L	Q_{O_2}[2]	Water Content[3] g/100 g wet wt	Tissue Volume[4,5] wet wt / dry wt	Reference
	(A)	(B)	(C)	(D)	(E)
	Liver, Guinea Pig				
1	0	3.8(2.9-4.8)	79.0(77.6-79.8)	1.28(1.19-1.36)	1,2
2	5	4.5(3.5-5.7)	76.0(72.8-78.7)	1.09(1.00-1.23)	1,2
3	10	5.0(4.0-6.1)	75.7(73.0-78.6)	1.08(0.97-1.16)	1,2
4	20	5.2(4.1-6.1)	75.5(73.2-77.9)	1.08(0.97-1.17)	1,2
5	40	5.1(4.1-6.2)	76.9(74.6-80.2)	1.11(0.99-1.32)	1,2
6	70	5.0(3.8-5.5)	78.0(75.3-81.4)	1.19(1.03-1.32)	1,2
	Kidney Cortex, Rabbit				
7	0	14.7(12.5-18.0)	76.0(73.0-79.7)	0.96(0.86-1.13)	3
8	5	15.8(14.5-17.5)	74.4(73.4-76.7)	0.90(0.87-0.99)	3
9	10	14.8(13.6-15.7)	75.0(73.2-78.2)	0.92(0.86-1.04)	3
10	20	15.3(14.1-16.9)	77.5(75.2-80.0)	1.02(0.93-1.15)	3
11	40	17.6(15.4-21.5)	81.4(79.6-83.3)	1.24(1.13-1.38)	3
12	55	19.4(18.0-20.6)	83.0(81.4-83.7)	1.36(1.24-1.42)	3
13	70	20.8(18.8-22.5)	85.2(84.2-86.5)	1.56(1.46-1.71)	3

/1/ Medium containing (155-X) mEq Na^+, X mEq K^+, 4.6 mEq Ca^{++} and 3.0 mEq Mg^{++}, buffered by 20 mM phosphate; pH = 7.15; addition of glucose, pyruvate, glutamate and fumarate as substrates (5 mM each). /2/ Estimated by Warburg's direct method at 37.5°C. /3/ Calculated from final wet weight and final dry weight of slices (dried in oven at 105°C until constant weight reached.) /4/ Calculated from change in wet weight per unit of tissue solids (dry weight), the wet weight/dry weight ratio of liver tissue or kidney cortex, removed immediately after death, being the reference base of the data. Per cent water content: fresh guinea pig liver, 73.65(71.1-76.6); rabbit kidney cortex, 76.8(73.6-78.6). /5/ Relative tissue volume in vivo = 1.0.

Contributor: Aebi, H.

References: [1] Aebi, H., Helvet. physiol. pharm. acta 10:184, 1952. [2] Aebi, H., unpublished. [3] Aebi, H., Helvet. physiol. pharm. acta 11:96, 1953.

Part II: RABBIT KIDNEY CORTEX, VARIOUS TEMPERATURES

	K^+ Concentration in Suspending Medium[1] mEq/L	Incubation Immediately after Death, 4°C	Incubation Immediately after Death, 22°C		Incubation after "Leaching," 25°C		Reference
		Water Content[2] g/100 g wet wt	Q_{O_2}[3]	Water Content[2] g/100 g wet wt	Q_{O_2}[4]	Water Content[5] g/100 g wet wt	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	0	79.9	4.4	74.0	2.9	79.2	B-D,1;E,F,2
2	10	80.1	4.7	74.8	3.5	79.2	B-D,1;E,F,2
3	20	80.4	4.2	76.2	3.4	79.5	B-D,1;E,F,2
4	40	81.6	4.8	80.3	2.9	79.0	B-D,1;E,F,2
5	55	81.5	4.7	82.1			B-D,1;E,F,2
6	70	81.8	4.6	83.9	2.5	81.0	B-D,1;E,F,2

/1/ Medium for Columns B, C and D containing (155-X) mEq Na^+, X mEq K^+, 4.6 mEq Ca^{++} and 3.0 mEq Mg^{++}, buffered by 20 mM phosphate; pH = 7.15; addition of glucose, pyruvate, glutamate and fumarate as substrates (5 mM each). Medium for E and F containing (150-X) mEq Na^+, X mEq K^+ and 1.4 mEq Ca^{++}, buffered by 3.7 mM phosphate; pH = 7.4; addition of 0.01 M Na-acetate as substrate. /2/ Calculated from final wet weight and final dry weight of slices (dried in oven at 105°C until constant weight reached). /3/ Estimated by Warburg's direct method. /4/ Original data were given on an initial wet weight basis and have been converted to a dry weight basis. /5/ Calculated as described in Footnote 2, but using different drying technique (dried in a vacuum oven over phosphorus pentoxide at 80°C).

Contributor: Aebi, H.

Reference: [1] Aebi, H., Helvet. physiol. pharm. acta 11:96, 1953. [2] Mudge, G. H., Am. J. Physiol. 165:113, 1951.

Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen per mg final dry weight of tissue per hour, unless otherwise indicated. Media are described in the appropriate footnotes in terms of quantity of ion per liter of solution.

Part III: RAT DIAPHRAGM, VARIOUS pH LEVELS

	pH	K^+ Concentration in Suspending Medium[1] mM/L	Q_{O_2}
	(A)	(B)	(C)
1	7.3	12	13.7
2		15	12.6
3		18	11.3
4		24	10.5
5		30	9.4
6	6.5	12	9.3
7		18	8.9
8		24	9.3
9		30	7.9
10	6.0	12	7.0
11		18	7.2
12		24	7.0
13		30	6.7
14	7.0	12	13.0
15		12[2]	14.6
16		12[3]	11.8

/1/ Medium containing (0.120-X) M NaCl, X M KCl, 0.0006 M $CaCl_2$, 0.0005 M $MgCl_2$, 0.03 M phosphate buffer, and 0.01 M pyruvate, except in Lines 15 and 16. /2/ Plus 0.01 M pyruvate. /3/ Plus 0.01 M glucose.

Contributor: Fitzgerald, L. R.

Reference: Frunder, H., Zschr. physiol. Chem. 291:217, 1953.

Part IV: RAT BRAIN, VARIOUS SUBSTRATES

	Final Concentration of Added KCl in Suspending Medium[1] mEq/L	Q_{O_2}[2] Glucose Substrate Before	Glucose Substrate 30 min after	Fructose Substrate Before	Fructose Substrate 30 min after	Lactate Substrate Before	Lactate Substrate 30 min after
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	2.4	10.2	10.5	10.0	10.1	15.0	14.5
2	52	10.4	20.6	12.2	24.7		
3	102	10.2	19.3	10.8	21.6	15.2	22.9

/1/ Initial ionic composition of medium: 120 mEq Na^+, 2.4 mEq K^+, 3.4 mEq Ca^{++}, 1.6 mEq Mg^{++}; buffered by 18 mM/L phosphate, pH = 7.4; concentration of added substrates, 11 mM/L. Additional amounts of potassium (as solid KCl) were added only after first incubation period (30 min). Values in Columns C, E and G are corresponding mean values for the 30-min period following addition of KCl. /2/ Estimated by Warburg's direct method at 37.5°C.

Contributor: Aebi, H.

Reference: Dickens, F., and Greville, G. D., Biochem. J., Lond. 29:1468, 1935.

Part V: RAT CEREBRAL CORTEX, VARIOUS SUBSTRATES

Medium: Krebs-Ringer solution with Ca^{++} reduced to 4.5×10^{-4} M, pH = 7.4.

	Substrate[1]	Q_{O_2} Control	Q_{O_2} +0.1 M KCl
	(A)	(B)	(C)
1	Glucose	10.0	17.5
2	L-Glutamate	6.0	4.7
3	Glucose + L-glutamate	12.0	12.2
4	Glucose + citrate	18.5	19.4
5	α-Ketoglutarate	4.5	4.0
6	Glucose + α-ketoglutarate	14.2	15.2
7	Succinate	9.2	5.9
8	Glucose + succinate	17.0	16.9
9	Glucose + succinate + 0.25M malonate	10.8	14.8
10	Glucose + L-asparate	10.3	15.7
11	Glucose + DL-methionine	9.3	20.3
12	Glucose + L-glutamine	14.5	21.1

/1/ All substrates present in 0.01 M quantities.

Contributor: Fitzgerald, L. R.

Reference: Lipsett, M. N., and Crescitelli, F., Arch. Biochem. and Biophys. 28:329, 1950.

Values for oxidation quotient (Q_{O_2}) are expressed in cu mm oxygen per mg final dry weight of tissue per hour, unless otherwise indicated. Media are described in the appropriate footnotes in terms of quantity of ion per liter of solution.

Part VI: GUINEA PIG CEREBRAL CORTEX, VARIOUS RELATIVE CONCENTRATIONS OF POTASSIUM AND SODIUM

	K^+ Concentration in Suspending Medium[1] mEq/L	Q_{O_2} Isotonic Medium (Na + K = 0.162 M)	Hypertonic Medium[2] (0.162 M Na + XK)	Hypertonic Medium (Na + K = 0.303 M)
	(A)	(B)	(C)	(D)
1	0	9.4	9.7	2.8
2	0.001	10.1		
3	0.005	13.9		
4	0.010	14.8	15.4	
5	0.020	18.4		
6	0.040	21.1	21.2	12.0
7	0.080			15.7
8	0.143	6.5	15.2	
9	0.152			17.1
10	0.220			12.3
11	0.285			6.9

/1/ Besides the above indicated Na- and K-ion concentration, all media contain 0.01 M phosphate as a buffer, and 0.1% glucose as substrate; pH = 7.5. /2/ X = concentration of K^+ shown in Column A.
Contributor: Aebi, H.
Reference: Canzanelli, A., Rogers, G., and Rapport, D., Am. J. Physiol. 135:309, 1941-42.

Part VII: RAT AND RABBIT, VARIOUS TISSUES

Medium: Ringer's solution.

	Tissue	Q_{O_2} Control	$+2.9 \times 10^{-3}$ M KCl[1]	Reference
	(A)	(B)	(C)	(D)
	Rat			
1	Liver	9.7	5.6	1
2	Kidney	18.4	17.4	1
3	Spleen	12.9	12.2	1
4	Cerebral cortex	3.6	1.9	1
5	Liver (embryo)	10.8	10.7	1
6	Kidney (embryo)	12.6	13.4	1
	Rabbit			
7	Brain	7.1	14.1	2

/1/ Except for rabbit brain where KCl added was 0.1 M.
Contributor: Fitzgerald, L. R.
References: [1] Lasnitsky, A., C. rend. Soc. biol. 143:967, 1949. [2] Ashford, C. A., and Dixon, K. C., Biochem. J., Lond. 29:157, 1935.

Part VIII: FROG SCIATIC NERVE

Medium: Ringer's solution or isotonic NaCl (no significant difference).

	KCl %	Q_{O_2} Decrease %
	(A)	(B)
1	10	0
2	20	17
3	30	26
4	40	34
5	50	43
6	70	44
7	80	50
8	100	50

Contributor: Fitzgerald, L. R.

Reference: Chang, T. H., Schaffer, M., and Gerard, R. W., Am. J. Physiol. 111:681, 1935.

Part IX: CRAB LIMB NERVE

Values are expressed in μl per gram wet weight of tissue per hour. Species of crab used were mainly Libinia emarginata and Grapsus grapsus.

	K^+ Concentration in Suspending Medium[1] mM/L	Q_{O_2}
	(A)	(B)
1	0	90.6
2	5	90.1
3	10	86.5
4	15	131.1
5	20	146.3
6	30	162.0
7	40	144.0
8	50	100.8
9	70	69.7
10	100	47.9
11	Sea water	115.7

/1/ Artificial sea water.
Contributor: Fitzgerald, L. R.
Reference: Shanes, A. M., and Hopkins, H. S., J. Neurophysiol. 11:331, 1948.

154. SURVIVAL AND REVIVAL UNDER CONDITIONS OF ANOXIA OR ARRESTED CIRCULATION: ANIMAL TISSUES

Adult tissue, in situ, at room temperature, normal body temperature, unless otherwise indicated. N = anoxia produced by cessation of respiration or by administration of nitrogen to animal or to isolated tissue; C = circulation arrested by obstructing or bypassing total afferent blood supply to organ.

	Tissue	Animal	Survival Time[1]		Revival Time[2]		References
			min	Condition	min	Condition	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Brain, cerebral cortex	Cat	1/6-1/4	C	<3	C	C,D,1,2;E,F,3
2		Cat			>5-10	C	4
3		Dog			1-8	C	5,6
4		Dog[3]			12-20	C	5,6
5		Rabbit	1/3-2	N			7
6		Rat	1-1 1/2	N			8
	Brain stem						
7	Telencephalon and mesencephalon	Rabbit	1/3-4	N			7
8	Pupillary centers	Dog	3-4	C[4]			9
9	Medulla	Rabbit	1/2-8	N			7
10	Cardioregulatory, vasomotor, and adrenosecretory centers	Dog	4-5	C[4]	15-30	C[4]	9
11		Dog			5-10	C	10
12	Respiratory center	Dog, rat	4-5	C[4]	15-30	C	9
13		Dog, rat	1/3-1/2	C			6,11
14		Rat[3]	20-40	C[5]			11
15	Spinal cord	Cat	2/3-1	C	35-45	C	C,D,12;E,F,13
16		Cat			90-120	C	14
17		Rabbit	2/3-2	C			15
18	Autonomic synapses	Cat	30-40	N, C[6]	120-360+	N[7]	16
19	Peripheral nerve	Cat, dog, rabbit	15-45	N[8]			17,18
20		Frog	70-360	N[8]			18
21		Lobster	40-120	N[8]			18
22	Heart	Dog, rabbit, rat	5-20	C			19
23		Dog, rabbit, rat	4-6	N	8-11	N	20
24		Dog, rabbit, rat[3]	47-111	N			21
25	Lung	Dog			30-45	C[9]	22
26	Kidney	Dog			30-60	C[9]	23,24
27		Dog			>120	C[9]	25,26
28		Rabbit			60-90	C[9]	27
29		Rat			<120	C[9]	26,28
30	Liver	Dog			20-75	C[9]	29-32
31		Dog			>60[10]	C[9]	31
32	Skeletal muscle	Dog, rabbit, rat	120-360	C	480	C	33,34
33	Smooth muscle, jejunum	Rabbit	1-15	N[8]	>180	N	35
34	Small intestine	Dog			120-240+	C[11]	36
35	Testis	Rat[12]			10-30	C	37

/1/ Period of anoxia or circulatory arrest during which function persists. /2/ Period of anoxia or circulatory arrest compatible with complete recovery of function, i.e., before irreversible changes occur. /3/ Newborn. /4/ Isolated, perfused head. /5/ Decapitated. /6/ Intact and isolated ganglia. /7/ 25% recovery at 6 hr. /8/ Isolated, in vitro. /9/ Criterion: death of animal. /10/ Value for liver at 24°-27°C. /11/ Criteria: electrical reaction and death of animal. /12/ Histological study of spermatogenesis.

Contributors: (a) Sonnenschein, R. R., Lewis, R., and Darling, L., (b) Van Harreveld, A., (c) Wesolowski, S. A.

References: [1] Sugar, O., and Gerard, R. W., J. Neurophysiol. 1:558, 1938. [2] Van Harreveld, A., ibid 5:361, 1947. [3] Gänshirt, H., and Zylka, W., Arch. Psychiat., Berl. 189:23, 1952. [4] Ten Cate, J., and Horsten, G. P., Arch. internat. physiol., Liége 62:6, 1954. [5] Kabat, H., and Dennis, C., Proc. Soc. Exp. Biol. 42:534, 1939. [6] Kabat, H., Am. J. Physiol. 130:588, 1940. [7] Albaum, H. G., et al, ibid 174:408, 1953. [8] Soulairac, A., C. rend. Acad. sc. 234:2565, 1952. [9] Heymans, C., et al, Arch. Neur. Psychiat., Chic. 38:304, 1937. [10] Malmejac, J., and Plane, P., Afrique fr. chir. 12:435, 1954. [11] Selle, W. A., and Witten, T. A., Proc. Soc. Exp. Biol. 47:495, 1941. [12] Van Harreveld, A., Am. J. Physiol. 141:97, 1944. [13] Van Harreveld, A., and Marmont, G., J. Neurophysiol. 2:101, 1939. [14] Van Harreveld, A., and Tyler, D. B., Am. J. Physiol. 142:32, 1944. [15] Blasius, W., Zschr. Biol. 104:121, 1951. [16] Bronk, D. W., et al, J. Cellul. Physiol. 31:193, 1948. [17] Lehmann, J. E., Am. J. Physiol. 119:11, 1937. [18] Wright, E. B., ibid 147:78, 1946. [19] Wesolowski, S. A., et al, in "Surgical Forum," p 270, Philadelphia: W. B. Saunders Co., 1952. [20] Binet, L., and Strumza, M., C. rend. Acad. sc. 226:1491, 1948. [21] Selle, W. A., Proc. Soc. Exp. Biol. 48:417, 1941. [22] Blades, B., Arch. Surg. 69:525, 1954. [23] Guthrie, C. C., Arch. Int. M. 5:232, 1910. [24] McEnery, E. J., et al, J. Laborat. Clin. M. 12:349, 1926. [25] Friedman, S. M., et al, Circulation Res. 2:231, 1954. [26] Scheibe, J. R., et al, Surgery 25:724, 1949. [27] Badenoch, A. W., and Darmedy, E. M., J. Path. Bact., Lond. 59:79, 1947. [28] Latorre, G., J. Urol., Balt. 72:639, 1954. [29] Raffucci, F. L., Surgery 33:342, 1953. [30] Drapanas, T., et al, Ann. Surg. 142:831, 1955. [31] Bernhard, W. F., et al, N. England J. M. 253:159, 1955. [32] Hines, J. R., and Roncoroni, M., Surg. Gyn. Obst. 102:689, 1956. [33] Harmon, J. W., Am. J. Path. 23:551, 1947. [34] Harmon, J. W., and Gwinn, R. P., ibid 25:741, 1949. [35] Furchgott, R. F., and Shorr, W., Am. J. Physiol. 162:88, 1950. [36] Enquist, I. F., and Kremen, A. J. in "Surgical Forum," p 87, Philadelphia. W. B. Saunders Co., 1952. [37] Oettle, A. G., and Harrison, R. G., J. Path. Bact., Lond. 64:273, 1952.

Values determined in vivo for unanesthetized animal, unless otherwise indicated. Values in parentheses are ranges and, unless otherwise specified, conform to estimate "c" of the 95% range (cf Introduction). Note that 100 x Column E ÷ Column C = brain arterio-venous O_2 difference, the quantity of O_2 removed by the brain from each 100 ml of blood flowing through it.

	Species	Condition	Blood Flow ml/100 g/min	O_2 Consumption ml/100 g/min	Vascular Resistance mm Hg/ml/100 g/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Man[1]	Alert[2, 3]	54 (40-79)	3.3 (2.6-4.2)	1.6 (0.8-2.4)	3, 4
2		Inhalation 5-7% CO_2[2]	93 (65-141)	3.3 (2.4-3.9)	1.1 (0.7-1.4)	5
3		Inhalation 85-100% O_2[2]	45 (34-55)	3.2 (2.6-4.4)	2.2 (1.8-2.7)	5
4		Inhalation 10% O_2[2]	73 (54-93)	3.2 (2.6-3.5)	1.1 (0.8-1.6)	5
5		Cerebral arteriosclerosis	41 (31-56)	2.8 (1.7-3.6)	3.0 (1.9-3.5)	6
6		Thiopental anesthesia	60 (33-82)	2.1 (1.2-3.5)	1.3 (0.6-2.1)	7
7	Cat	Isolated perfused brain[4]		5.0 (3.9-6.1)[b]		8
8	Monkey, rhesus	Barbiturate anesthesia[4, 5]	48 (21-75)[6, b]	3.8 (2.4-5.2)[b]		9

/1/ Nitrous oxide method. /2/ Normal young men. /3/ Approximately same values and ranges (except for narrower ranges of blood flow) found in persons with essential hypertension [1], and in schizophrenics [2]. /4/ Active reflexes, spontaneous movements. /5/ Light anesthesia. /6/ Measured by intercalated bubble flow meter.

Contributor: Kety, S. S.

References: [1] Kety, S. S., et al, J. Clin. Invest. 27:511, 1948. [2] Kety, S. S., et al, Am. J. Psychiat. 104:765, 1948. [3] Kety, S. S., and Schmidt, C. F., J. Clin. Invest. 27:476, 1948. [4] Sokaloff, L., and Mangold, R., unpublished. [5] Kety, S. S., and Schmidt, C. F., J. Clin. Invest. 27:484, 1948. [6] Freyhan, F. A., et al, J. Nerv. Ment. Dis. 113:449, 1951. [7] Wechsler, R. L., et al, Anesthesiology 12:308, 1951. [8] Geiger, A., and Magnes, J., Am. J. Physiol. 149:517, 1947. [9] Schmidt, C. F., et al, ibid 143:33, 1945.

156. CEREBRAL RESPIRATION: DOG

Dogs received basic dose of 20 mg/kg of morphine sulfate. (In using this table, it should be remembered that morphine sulfate has a significant effect on blood respiratory characteristics [Rakieten, N., Himwich, H. E., and DuBois, D., J. Pharm. Exp. Ther. 52:437, 1934]).

Part I: CEREBRAL VS BLOOD GLUCOSE

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Condition	Arterial Blood Glucose mg/100 cc	Cerebral Tissue Glycogen mg/100 g	Cerebral Tissue Glucose mg/100 g
	(A)	(B)	(C)	(D)
1	Breathing air	210(180-240)	106(94-123)	102(88-115)
2	Breathing air with 6-9% CO_2	221(133-310)	117(116-118)	107(87-128)
3	Breathing O_2 with 5.5% CO_2	315	106	149
4	Breathing N_2 with 4.5-10% O_2	256(109-474)	97(57-140)	97(64-137)
5	Breathing N_2 with 3.5-6% O_2 and 5-6% CO_2	236(129-369)	127(109-144)	103(74-138)
6	Erythroidinized; hyperventilation with air	212(130-280)	122(119-127)	72(51-94)
7	Erythroidinized; hyperventilation with O_2	152(107-210)	122	56(37-78)

Contributors: (a) Gurdjian, E. S., (b) Smith, A. H.

Reference: Gurdjian, E. S., Webster, J. E., and Stone, W. E., Proc. Ass. Rev. Nervous and Mental Dis. 26:184, 1946.

Part II: CEREBRAL CONSTITUENTS VS BLOOD GASES

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Condition	Arterial Blood O_2 Tension mm Hg	Arterial Blood CO_2 Tension mm Hg	Arterial Blood Change in CO_2 Tension[1] mm Hg	Arterial Blood Lactic Acid mm/100 cc	Arterial Blood Glucose mg/100 cc
	(A)	(B)	(C)	(D)	(E)	(F)
1	Breathing air	59(53-63)	50(44-58)		11.1	210(180-240)
2	Breathing air with 5.5-9% CO_2	71(65-76)	79(70-88)	19(9-28)	23.6(17.7-31.9)	187(119-310)
3	Breathing O_2 with 5.5% CO_2	$\geq$150	73	17	10.7	315
4	Breathing mixtures low in O_2; acapnia	17(3-35)	33(18-47)	-17(-5 to -30)	60.9(30.9-143.0)	253(109-474)
5	Breathing mixtures low in O_2 with 5-6% CO_2	16(10-23)	55(42-68)	0(-16 to +16)	48.2(19.6-99.0)	236(129-369)
6	Erythroidinized; hyperventilation with air[2]	55(41-70)	24(12-39)	-27(-9 to -48)	37.0(22.2-55.0)	206(130-280)
7	Erythroidinized; hyperventilation with O_2[2]	129(87-150+)	17(16-18)	-32(-26 to -38)	27.3(19.2-31.5)	152(107-210)

	Condition	Venous Blood O_2 Tension mm Hg	Lactic Acid mg/100 g	Cerebral Tissue[3] Glucose mg/100 g	Cerebral Tissue[3] Glycogen mg/100 g	Cerebral Tissue[3] Inorganic P mg/100 g	Cerebral Tissue[3] Phosphocreatine P mg/100 g
	(A)	(G)	(H)	(I)	(J)	(K)	(L)
1	Breathing air	39(32-47)	12.2(9.1-13.8)	108(88-115)	106(94-123)	8.7	8.5(8.1-8.8)
2	Breathing air with 5.5-9% CO_2	53(50-55)	7.9(7.5-8.5)	107(87-128)	117(116-118)	8.4(7.6-9.0)	9.2(8.8-10.0)
3	Breathing O_2 with 5.5% CO_2	61	6.8	149	106	6.1	9.8
4	Breathing mixtures low in O_2; acapnia	8.8(0-17)	74(22.7-208)	97(64-137)	97(57-140)	12.4(8.1-19.9)	5.4(0.5-9.6)
5	Breathing mixtures low in O_2 with 5-6% CO_2	9.5(3-17)	35(16.4-76)	103(74-138)	127(109-144)	10.6(8.9-16.1)	6.7(2.6-8.6)
6	Erythroidinized; hyperventilation with air[2]	21(14-40)	21.7(9.8-37.8)	72(51-94)	122(119-127)	7.9(7.0-9.1)	9.8(9.0-10.9)
7	Erythroidinized; hyperventilation with O_2[2]	15	35.5(17-66)	56(37-78)	122	8.3	9.3

/1/ Increase or decrease from control level breathing air. /2/ Blood pressure decreased to a low level after blood specimens obtained. /3/ Determination of adenosine triphosphate (acid-labile and ribose monophosphate) reveals normal values in all classes of experiments except for low oxygen with acapnia, in which values about 25% lower than normal were obtained.

Contributors: (a) Gurdjian, E. S., (b) Smith, A. H.

Reference: Gurdjian, E. S., Webster, J. E., and Stone, W. E., Am. J. Physiol. 156:149, 1949.

Dogs received basic dose of 20 mg/kg of morphine sulfate. (In using this table, it should be remembered that morphine sulfate has a significant effect on blood respiratory characteristics [Rakieten, N., Himwich, H. E., and DuBois, D., J. Pharm. Exp. Ther. 52:437, 1934]).

Part III: CEREBRAL METABOLISM IN ANOXIA

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	O_2-N_2 Mixture % O_2	Time min	Femoral Artery Blood: O_2 Capacity vol %	Femoral Artery Blood: O_2 Saturation %	Femoral Artery Blood: CO_2 Content vol %	Femoral Artery Blood: Plasma Lactic Acid mg/100 g	Sagittal Sinus Blood: O_2 Saturation %	Sagittal Sinus Blood: A-V Differences O_2 vol %	Sagittal Sinus Blood: A-V Differences CO_2 vol %
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	4.2	15	23.3(22.5-24.2)	15.1(13.6-16.2)	23.9(16.9-35.4)	129(76-198)	5.9	1.9	6.7
2		20	19.7	11.2	12.8	152	4.3	1.4	4.0
3		24	20.5	13.1	15.4	243	8.3	1.0	7.0
4	5.0	15	18.0	22.8	28.5	76	13.9	1.6	4.1
5	5.8	15	25.0(23.1-26.6)	17.6(13.5-19.9)	41.4(34.9-49.2)	90(70-106)	11(8.7-12.2)	1.6(1.3-2.0)	0.8(0.3-1.3)
6	6.6	15	24.6	22.7	43.3	39	24	-0.3	0.3
7		15	21.4(17.8-24.7)	47.7(38.8-54)	40(31.8-44.4)	43(39-46)	24(22-25.5)	5(3.9-5.6)	6(4.2-7.1)
8		60	19.5	26.1	27.8	86.5(66-107)			
9	8.8	15	24.7(24.5-25.0)	42.8(38.4-47.3)	42.8(41.3-44.4)	66	24.2	5.7	5.7
10	10.2	15	25(23.6-26.4)	38(34.7-40.2)	44.6(38.2-51.1)	42(41-43)	21.3	3.2	10.4
11	11.6	15	19.6	61.3	43.6	16.9	42.3	3.7	3.8
12		60	22.8	49.1	40.1	34	26.1	5.3	5.7
13	13.0	15	21.3(20.3-21.9)	64.4(56.9-70)	42.4(40.3-45.7)	38	31(28.7-33.6)	7.0(6.0-7.1)	7.1(6.4-7.8)
14	21.0	5[1]	23.4	85.5	21.6	99			
15		10[1]	21.6(20-23.2)	79.5(75.5-83.6)	39.7(37.3-42.1)	34(27-42)	48.9(43.5-54.3)	6.6(6.4-6.8)	4.9(4.5-5.3)
16		13[1]	19.7	92.0	20.6	117	67.6	4.8	0.8
17		46[1]	20.5	93.7	43.1	47	51.7	8.6	12.4
18			23(20.3-23.2)	88.6(82.5-94.7)	41.0(33.4-48.6)	39.5(30-49)	55.2(49.8-60.7)	7.2(6.9-7.6)	6.6(5.9-7.4)
19			24.0(22.4-25.7)	91.7(86.2-97.2)	37.8(35.6-40.1)		73.0	3.9	-3.5

	O_2-N_2 Mixture % O_2	Time min	Cerebral Cortex Tissue: Lactic Acid mg/100 g, Right	Lactic Acid mg/100 g, Left	Inorganic P mg/100 g, Right	Inorganic P mg/100 g, Left	Phosphocreatine P mg/100 g, Right	Phosphocreatine P mg/100 g, Left
	(A)	(B)	(J)	(K)	(L)	(M)	(N)	(O)
1	4.2	15	121(93-157)	124(89-167)	11.9(10.1-13.9)	11.8(9.6-15.4)	4.4(3.0-5.9)	4.2(2.5-5.5)
2		20						
3		24						
4	5.0	15	70	76	8.6	9.4	7.5	7.2
5	5.8	15	86(72-95)	80(77-84)	10.5(9.7-11.4)	9.8(9.0-10.3)	6.3(5.5-7.6)	6.6(5.9-7.3)
6	6.6	15	55	51	9.4	8.3	7.5	7.9
7		15	60(55-64)	60(53-67)	7.8(7.0-8.5)			7.7(7.3-8.1)
8		60	49(48-49)	47(45-48)	8.3(7.7-9.0)	8.1(7.9-8.4)	7.3(7.3-7.4)	7.3(7.1-7.6)
9	8.8	15	34	31(30-33)	7.5(7.2-7.8)	6.8	9.9(9.2-10.6)	9.7(9.0-10.3)
10	10.2	15	37(33-40)	41(34-47)	8.1(7.7-8.6)	8.2(7.7-8.7)	8.1(7.9-8.3)	8.1(7.6-8.7)
11	11.6	15	21	20	9.5	8.9	8.7	8.9
12		60	19	16	9.1	7.9	8.6	9.0
13	13.0	15	13(9.1-16.8)	12(10.2-14.0)	7.8(7.0-8.6)	7.4(6.2-8.7)	9.6(7.4-11.2)	8.7(7.8-9.7)
14	21.0	5[1]	90	71	6.1	5.7	8.1	9.8
15		10[1]	17(13.5-19.9)	17(15.8-17.2)	7.8(7.2-8.4)	7.7(7.5-8.0)	11.0(10.9-11.2)	10.6(10.5-10.8)
16		13[1]	90	66	7.6	8.0	8.0	8.5
17		46[1]	19	26	7.7	8.1	8.8	8.0
18			13(9.5-17.2)	11(9.5-12.1)	7.6(6.6-8.7)	7.1(6.9-7.4)	8.7(7.8-9.6)	8.8(8.7-8.9)
19			11(10.2-11.6)[2]		7.7(7.2-8.2)[2]		10.6(10.2-11.0)[2]	

/1/ After anoxia. /2/ Side not indicated.

Contributors: (a) Gurdjian, E. S., (b) Smith, A. H.

Reference: Gurdjian, E. S., Stone, W. E., and Webster, J. E., Arch. Neur. Psychiat. 51:472, 1944.

Rate and degree of respiration of bacteria may be affected by numerous factors, such as strain characteristics, composition of growth medium, age and number of cells in an inoculum, origin of inoculum, age of culture harvested for study, nature of solution used for washing, number of washings, and composition of the respiratory system. Values are µl/mg dry weight/hour. Data are for bacterial suspensions in the presence of glucose.

	Species	Temp °C	Culture Age hr	Q_{O_2} µl/mg/hr	Reference
	(A)	(B)	(C)	(D)	(E)
1	Aerobacter aerogenes	36, 30	17, 48	47, 50	1, 2
2	Azotobacter chroococcum	22	36	2,000-10,000	3
3	Bacillus cereus (short)	30	18	42-86	4
4	B. cereus (filamentous)	30	18	3-49	4
5	B. subtilis	37	6-8	170	5
6	B. subtilis (spores)	32	98-147	10	6
7	Corynebacterium sp	30	48-96	67	7
8	Escherichia coli	40, 32	20	200, 272	1, 8
9	Lactobacillus brulgaricus	37, 45	8	34, 55	9
10	Leuconostoc citrovorum	38	16	8	10
11	Micrococcus auranticus	35	30-34	14	11
12	M. cinnebareus	35	30-34	32	11
13	M. flavus	35	30-34	8	11
14	M. freundenreichii	35	30-34	20	11
15	M. luteus	35	30-34	15	11
16	Mycobacterium sp (Karlinski)	38	84	22	12
17	M. butyricum	38	84	13	12
18	M. leprous kedrowsky	38	84	8	12
19	M. phlei	38	84	28	12
20	M. ranae	38	84	32	12
21	M. smegmatis	38	84	23	12
22	M. stercoris	38	84	15	12
23	M. tuberculosis avian	37	84	1	13
24	M. tuberculosis hominis	38	252	4	12
25	Pneumococcus, type 1	37	18	27	14
26	Pseudomonas fluorescens	26	20	58	15
27	Streptococcus faecalis, B 33 A	38	18	106	16
28	S. faecalis, 10 Cl	37	15	57-80	17
29	S. faecalis, Lancefield D	37	12-15	7	18
30	S. pyogenes, C 203 M	37.5	4	57-163	19
31	S. pyogenes, C 203 S	37.5	4	99-113	19
32	S. thermophilus, C 3	37, 50	8	4, 5	9
33	S. thermophilus, MC	37, 50	8	9, 10	9
34	Streptomyces coelicolor		72	35	20

Contributor: Silverman, M.

References: [1] Ajl, S. J., J. Bact., Balt. 59:499, 1950. [2] Ajl, S. J., and Wong, T. O., ibid 61:379, 1951. [3] Meyerhof, O., and Burk, D., Zschr. phys. Chem. A 139:117, 1928. [4] Nickerson, W. J., and Sherman, F. G., J. Bact., Balt. 64:667, 1952. [5] Gary, N. D., and Bard, R. C., ibid 64:501, 1952. [6] Crook, P. G., ibid 63:193, 1952. [7] Levine, S., and Krampitz, L. O., ibid 64:645, 1952. [8] Krebs, H. A., Biochem. J., Lond. 31:2095, 1937. [9] Stein, R. M., and Frazier, W. L., J. Bact., Balt. 42:501, 1941. [10] Chang, S. C., Silverman, M., and Keresztesy, J. C., ibid 62:753, 1951. [11] Nunheimer, T. D., and Fabian, F. W., ibid 44:215, 1942. [12] Edson, N. L., and Hunter, G. J., Biochem. J. 37:563, 1943. [13] Oginsky, E. L., Smith, P. H., and Solotorovsky, M., J. Bact., Balt. 59:29, 1950. [14] Bernheim, F., and Bernheim, M. L., ibid 46:225, 1943. [15] Sebek, O. K., and Randles, C. I., ibid 63:693, 1952. [16] Seeley, H. W., and Vandemark, P. J., ibid 61:27, 1951. [17] O'Kane, D. J., ibid 60:449, 1950. [18] Gunsalas, I. C., and Umbreit, W. W., ibid 49:347, 1945. [19] Sevag, M. G., and Shelburne, M., ibid 43:411, 1942. [20] Cochrane, V. W., and Gibbs, M., ibid 61:305, 1951.

158. RESPIRATION RATES: ALGAE

Values for rates of gaseous exchange are µl/100 mg dry weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Blue Green							
1	Anabaena sp	25	Mano	460		0.90		1
2	A. variabilis	25	Mano	170-840[2]		1.0-1.1	Starved, growing	2
3	Anacystis nidulans	25	Mano	30-160[2]		0.9-1.0	Starved, growing	2
4		39	Mano	190-750[2]		1.1	Starved, growing	2
5	Nostoc commune	19	Mano	0.4[3]		0.40		3
6	N. muscorum	25	Mano	110-440[2]			Starved, growing	2
	Green							
7	Chara vulgaris	18	Chem		1.5[3]			4
8	Chlorella sp	27	Mano	167-367[2]			Mutants	5
9		28	Mano	89-1537[4]			Inorganic nutrients	6
10		28	Mano			0.38-1.48	Carbohydrate substrates; organic acids	6
11		39	Mano	600-2500[2]		1.2-1.5	Period between cell division, endogenous	7
12		39	Mano	2500-4000[2]			Period between cell division, glucose	7
13	C. ellipsoidea	25	Mano	147			Various substrates	8
14	C. pyrenoidea	20	Mano	100				9
15			Mano	220-500			Various substrates	9
16		20	Mano	100		0.89	Various substrates	10
17	C. pyrenoidosa	3.5	Mano	150-200		0.98	Carbohydrate substrates	11
18		18	Mano	430-890		0.94	Carbohydrate substrates	11
19		25	Mano	420-820		0.93-1.10	Metabolic poisons	12
20			Mano	2000			Carbohydrate substrates	12
21		25	Mano	35-150[2]		0.9-1.1	Starved, growing	13
22		20	Mano	1700		1.39	Carbohydrate substrates	14
23		30	Mano	52-23[2]			Metabolic poisons	15
24		23	Mano	48[2]				16
25		15	Mano	12-24[4]			Carbohydrate substrates	17
26		15	Mano	85-170			Carbohydrate substrates	18
27		20	Mano	57[2]			Light	19
28	C. variegata	20	Mano			0.95-2.1	Various substrates	14
29	C. vulgaris	20	Mano	475-192[4]			Growth, development	20
30	Cladophora sp		Chem	74				21
31		12	Chem	9[3]				22
32	C. arcta		Chem	91				21
33	C. rupestris		Chem	49				21
34		20	Chem	33				23
35	C. sericea		Chem	85				21
36	Coelastrum proboscideum	20	Mano	170				9
37		20	Mano	280-1270			Various substrates	9
38	Enteromorpha compressa	20	Chem		27	3.6		24
39		20	Chem	67				23
40			Chem	140				21
41	E. linza	19	Chem		66	0.62		22
42			Chem	140				21
43		25	Mano	129			Various substrates	8
44	Haematococcus pluvialis	20	Mano	180				9,10
45		20	Mano	180			Carbohydrate substrates	9

46	Monostroma grevillei		Chem	150				21
47	Nitella flexilis	18	Chem		1.6[3]			4
48	Prasiola crispa	18.5	Chem	1-126			Moisture	25
49	Pseudendoclonium brasiliense	20	Mano	110				10
50		20	Mano	100-210			Various substrates	9
51	Scenedesmus sp, D-1	20	Mano	700			Carbohydrate substrates	14
52	Scenedesmus sp, D-3	23	Mano	222[2]				16
53		25	Mano	130-180			pH	13
54			Mano	180-410			Metabolic poisons	13
55	S. brasiliensis	20	Mano	140				9, 10
56		20	Mano			0.92-1.80	Various substrates	14
57			Mano	180-750			Various substrates	9
58	S. obliquus	25	Mano	50			pH	13
59		20	Mano			1.15		14
60	Spirogyra majuscula	10.4	Chem	0.5[3]			pH	26
61	S. rivularis		Chem	3.8[3]			pH	26
62	S. varians	10.4	Chem	0.58[3]			pH	26
63	Stichococcus bacillaris	20	Mano	140				9, 10
64		20	Mano	140-620			Various substrates	9
65	Trebouxia sp	18.5	Chem	1.8-30.0			Moisture	25
66	Ulothrix flacca		Chem	160				21
67	Ulva lactuca	20	Chem	91				23
68			Chem	150				21
69		20	Chem		13-16	2.35-6.1	Oxygen	24
70		25	Mano	81			Various substrates	8
71		12	Chem	56		0.95		27
72		18	Chem		50	0.67		22
73	U. linza	17	Chem	90				27
74	Urospora penicillioides		Chem	160				21
75	Valonia utricularis	20	Chem		8.4	1.5-5.7	Oxygen	24
				Brown				
76	Ascophyllum nodosum		Chem	14				21
77		20	Mano	1.9[3]		0.80		28
78	Chorda filum		Chem	150				21
79	C. tomentosa	9	Chem	74				22
80			Chem	63				21
81	Chordaria flagelliformis		Chem	130				21
82	Cladostephus spongiosus	20	Chem	39				23
83	Cutleria multifida	20	Chem		7.2-17.0	0.53-2.10	Oxygen	24
84	Cystoseira abrotanifolia	20	Chem		4.5-10.0	1.2-3.7		24
85	C. amentacea	20	Chem		17	3.9		24
86	C. barbata	20	Chem		13-17	2.1-4.0	Oxygen	24
87	Desmarestia aculeata	14	Chem	24[3]				22
88			Chem	120				21
89		20	Chem	27				23
90	D. viridis		Chem	170				21
91		14	Chem	14[2]				22
92	Dictyota dichotoma	20	Chem		9.4-9.2	0.98-1.04	Oxygen	24
93	Ectocarpus siliculosus	12	Chem	41[3]				22
94			Chem	140				21
95	E. tomentosus		Chem	60				21
96	Fucus sp	17	Mano		1.1[5]	0.26		29
97		9	Mano		1.2[5]	0.43		29

/1/ Mano = manometric, Chem = chemical. /2/ µl/100 µl cell volume/hour. (To convert to dry-weight basis for Chlorella: 1 µl cell volume = 0.20-0.25 mg dry weight.) /3/ µl/100 mg wet weight/hour. /4/ µl/10^9 cells/hour. /5/ µl/sq cm/hour.

158. RESPIRATION RATES: ALGAE (Concluded)

Values for rates of gaseous exchange are µl/100 mg dry weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
				Brown (concluded)				
98	Fucus canaliculatus	15	Mano			0.50		3
99	F. platycarpus		Chem	19				21
100	F. serratus	20	Chem	18				23
101		18	Chem		18	0.54		22
102			Chem	35				21
103		17	Chem	19		0.99		27
104		18	Mano	2.8[3]		0.74		28
105	F. vesiculosus	20	Chem	25				23
106			Chem	34				21
107		17	Chem		11	0.60		22
108		18	Mano	5.1[3]		0.78		28
109		18	Mano	20[2]				30
110		18	Mano	255[2]			Antherozoids	30
111		18	Mano	54-100[2]			Eggs; fertilization	30
112	Halidrys siliquosa		Chem	33				21
113	Laminaria digitata	5	Mano		0.9[5]	0.67		29
114		17	Chem	2[3]				22
115			Chem	23				21
116	L. hyperborea		Chem	86				21
117	L. phyllitis		Chem	91				21
118	L. saccharina	20	Chem	7				23
119			Chem	80				21
120		15	Chem	7				27
121		5	Mano		2.1[5]	0.80		29
122	Myelophycus caespitosus	25	Mano	46			Various substrates	8
123	Pogotrichum filiformis		Chem	210				21
124	Punctaria sp		Chem	72				21
125	P. plantaginea		Chem	73				21
126	Sargassum linifolium	20	Chem		24	5.5		24
127	Scytosiphon lomentarius	25	Mano	150			Various substrates	8
128			Chem	290				21
129	Taonia atomaria	20	Chem		6.7-20.0	0.91-3.10	Oxygen	24
				Red				
130	Batrachospermum moniliforme	20	Chem	64				23
131	Ceramium rubrum	17	Chem		45	0.89		22
132	Chondrus crispus		Chem	38				21
133		23	Mano	2.8[3]		0.81		28
134		14	Chem	18				27
135		20	Chem	28				23
136	Cryptonemia lomation	20	Chem		7.5-9.9	2.4-3.8	Oxygen	24
137	Cystoclonium purpurascens		Chem	65				21
138	Delesseria alata		Chem	51				21
139		20	Chem	41				23

140	D. sanguinea		Chem	110				21
141	D. sinuosa		Chem	67				21
142	Dumontia filiformis		Chem	140				21
143	Furcellaria fastigiata	14	Chem	33				22
144			Chem	38				21
145		20	Chem	12				23
146		14	Chem	7				27
147	Gelidium amansii	25	Mano	85			Various substrates	8
148	G. corneum	20	Chem		13	3.26		24
149	Gigartina teedii	12	Chem	49		0.98		27
150	Gloiopeltis complanata	25	Mano	63			Various substrates	8
151	Gracilaria compressa	20	Chem		9	1.4		24
152	G. confervoides	20	Chem		15-16	2.2-4.1	Oxygen	24
153		25	Mano	164			Various substrates	8
154	Grateloupia consentinii	20	Chem		4.2	1.49		24
155	G. proteus	20	Chem		8.8	4.5		24
156	Laurencia papillosa	20	Chem		18	4.88		24
157	Phyllophora sp		Chem	66				21
158	P. nervosa	20	Chem		4.6	1.56		24
159	P. brodiaei		Chem	67				21
160	Plocamium coccineum	14	Chem	21				27
161			Chem	46				21
162		20	Chem	21				23
163	Polyides lumbricoides	14	Chem	5				27
164	P. rotundus		Chem	36				21
165	Polysiphonia urceolata		Chem	130				21
166		12	Chem	10^3				22
167	P. violacea	11	Chem		107	1.02		22
168	Porphyra lacinlata	17	Chem	39				27
169			Mano	63				22
170	P. leucosticta		Chem	86				21
171	P. tenera	25	Mano	155			Various substrates	8
172	Rhodomela subfusca		Chem	160				21

/1/ Mano = manometric, Chem = chemical. /2/ µl/100 µl cell volume/hour. /3/ µl/100 mg wet weight/hour. /5/ µl/sq cm/hour.

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159. RESPIRATION RATES: LICHENS

Values for rates of gaseous exchange are µl/100 mg dry weight/hour, unless otherwise specified.

	Species	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Alectoria nigricans	30	Mano	33			1
2		10	Mano	14			1
3		0	Mano	8			1
4	Cetraria chrysantha	30	Mano	19			1
5		10	Mano	9			1
6		0	Mano	3.9			1
7	C. cucullata	30	Mano	20			1
8		10	Mano	10			1
9		0	Mano	4.3			1
10	C. glauca	30	Chem		61		2
11		20	Chem		31		2
12		0	Chem		10		2
13	C. islandica	30	Chem		31		2
14		20	Chem		13		2
15		0	Chem		2.5		2
16		30	Mano	48			1
17		10	Mano	19			1
18		0	Mano	8			1
19	C. nivalis	30	Mano	31			1
20		10	Mano	10			1
21		0	Mano	4.2			1
22	C. richardsonii	30	Mano	24			1
23		10	Mano	6.9			1
24		0	Mano	2.9			1
25	Cladonia furcata		Mano			0.84	3
26	C. rangiferina		Mano		16-103[2]	0.80	3
27		50	Mano		8	0.80	3
28	C. scholanderi	30	Mano	13			1
29		10	Mano	7.5			1
30		0	Mano	3.1			1
31	C. sylvatica	30	Mano	24			1
32		10	Mano	6.8			1
33		0	Mano	2.9			1
34	Cornicularia divergens	30	Mano	40			1
35		10	Mano	11			1
36		0	Mano	5			1
37	Dactylina arctica	30	Mano	41			1
38		10	Mano	14			1
39		0	Mano	7			1
40	Evernia prunastri		Mano		37-30[2]	0.81	3
41		50	Mano		31	0.78	3
42		60	Mano		27	0.88	3
69	P. olivaria		Cond		17		5
70	P. physodes		Cond		12		5
71		18.5	Chem	3-40[2]			6
72	P. saxatilis		Cond		40-70[2]		5
73	P. subaurifera		Cond		50-100[2]		5
74	Peltigera aphthosa	30	Mano	90			1
75		10	Mano	33			1
76		0	Mano	17			1
77	P. canina	30	Mano	68			1
78		10	Mano	36			1
79		0	Mano	12			1
80		20	Chem		15.3[3]		7
81		25			19[4,5]		8
82	P. polydactyla	25			14[4,5]		8
83	P. subamericana	30	Mano	42			1
84		10	Mano	19			1
85		0	Mano	5.7			1
86	Pertusaria amara		Mano			0.83	3
87	P. communis		Mano			0.84	3
88	Physcia aipolia		Mano			0.73	3
89	P. ciliaris		Mano		23	0.80	3
90		45	Mano		14	0.80	3
91	P. parientina		Mano		48	0.83	3
92	Ramalina alludens	30	Mano	13			1
93		10	Mano	3.3			1
94		0	Mano	2.2			1
95	R. dendrescoides	30	Mano	17			1
96		10	Mano	9			1
97		0	Mano	4			1
98	R. farinacea		Mano		24	0.75	3
99		50	Mano		19	0.77	3
100		30	Chem		71		2
101		20	Chem		41		2
102		0	Chem		5		2
103	R. fraxinea		Mano		17	0.79	3
104		45	Mano		19	0.88	3
105	R. leptosperma	30	Mano	16			1
106		10	Mano	6.9			1
107		0	Mano	3.8			1
108	R. usnea	30	Mano	16			1
109		10	Mano	7			1
110		0	Mano	3.5			1

43		30	Chem		66		2
44		20	Chem		31		2
45		0	Chem		5		2
46	Lecanora haematomma		Mano			0.80	3
47	L. subfusca		Mano			0.80	3
48	Lecidea superans		Mano			0.85	3
49	Lobaria linita	30	Mano	72			1
50		10	Mano	22			1
51		0	Mano	10			1
52	L. pulmonaria	27	Chem		1-26[2]		4
53	L. scrobiculata	30	Mano	50			1
54		10	Mano	29			1
55		0	Mano	12			1
56	Omphalodiscus	30	Mano	27			1
57	decussatus	10	Mano	6.2			1
58		0	Mano	3.1			1
59	Opegrapha notha		Mano			0.74	3
60	Parmelia acetabulum		Mano		2.3	0.79	3
61	P. caperata		Mano		25	0.75	3
62	P. centrifuga	30	Mano	20			1
63		10	Mano	8.5			1
64		0	Mano	2.4			1
65	P. furfuracea		Cond		10		5
66	P. nigrociliata	30	Mano	25			1
67		10	Mano	13			1
68		0	Mano	4			1

111	Solorina crocea	30	Mano	43			1
112		10	Mano	24			1
113		0	Mano	10			1
114	Sticta laciniata	30	Mano	28			1
115		10	Mano	11			1
116		0	Mano	7			1
117	S. weigelii	30	Mano	40			1
118		10	Mano	14			1
119		0	Mano	6.7			1
120	Teloschistes flavicans	30	Mano	24			1
121		10	Mano	11			1
122		0	Mano	5			1
123			Chem, Cond		0.6-52.0[2]		9
124	Thamnolia vermicularis	30	Mano	28			1
125		10	Mano	14			1
126		0	Mano	4.2			1
127	Umbilicaria	30	Mano	30			1
128	cinereorufescens	10	Mano	9.8			1
129		0	Mano	4.1			1
130	U. proboscidea	30	Mano	18			1
131		10	Mano	6.5			1
132		0	Mano	3.5			1
133	U. pustulata		Mano		77-540[2]		3
134		28	Chem		11-22[2]		4
135	Usnea dasypoga		Cond		60-90[2]		5

/1/ Mano = manometric; Chem = chemical; Cond = conductometric. /2/ Effect of moisture. /3/ µl/sq cm/hour. /4/ µl/100 mg wet weight/hour. /5/ Effect of temperature.

Contributors: Mandels, G. R., and Darby, R. T.

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Values for rates of gaseous exchange are given in µl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate µl/mg/hr Q_{O_2}	Respiration Rate µl/mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Myxomycetes					
1	Physarum polycephalum	Plasmodium	22	Mano	End	10;50;300 mg/vessel.	0.25[3]-1.4[3]-0.4[3]			Method	1
2		Plasmodium	22	Mano		50 mg/vessel.		1.0[3]-$\underline{0.24}$[3]	0.75-0.85		1
3		Plasmodium		Mano			15[3]		0.8		2
4		Plasmodium	25	Mano	End	PO_4 buffer, pH 6.0, 0 da.	1.08[3]	$\underline{0.11}$[3]	0.83	Substrate	3
						Phycomycetes					
5	Allomyces arbuscula	Mycelia[4]	20	Mano	Org	+0.1M glutamate.	0.84			Substrate	4
6		Mycelia[4]	28	Mano	End	Starved.	1.5-17.9			Starvation	5
7	A. cystogenus	Mycelia[4]	20	Mano	Org	+0.1M glutamate.	0.88			Substrate	4
8	A. javanicus	Mycelia[4]	20	Mano	Org	+0.1M glutamate.	0.69			Substrate	4
9	A. moniliformis	Mycelia[4]	20	Mano	Org	+0.1M glutamate.	1.03			Substrate	4
10	Leptomitus lacteus	Pellets	20	Mano	End	Starved 0;4;8 hr.	20-15-10			Hr starved	6
11		Pellets	20	Mano	Org	+D, L-Alanine, 2-5 hr.	35-40			Substrate; age	6
12		Pellets	20	Mano	Org	+L-Leucine, 1-4 hr.	30-40			Substrate; age	6
13		Pellets	20	Mano	Org	+Glycine, 2-6 hr.	18-16			Substrate; age	6
14		Pellets	20	Mano	Org	Endogenous.			0.98	Substrate	6
15		Pellets	20	Mano	Org	+D, L-Alanine.			0.99	Substrate	6
16		Pellets	20	Mano	Org	+Glycine.			1.12	Substrate	6
17		Pellets	20	Mano	Org	+L-Leucine.			0.64	Substrate	6
18		Pellets	20	Mano	Org	+Acetate.			0.98	Substrate	6
19		Pellets	20	Mano	Org	+Butyrate.			0.83	Substrate	6
20	Mucor guilliermondi	Mycelia	25	Mano	End	Mycelial phase.	5.7-10.0	$\underline{7.1}$		Substrate	7
21		Mycelia	25	Mano	CHO	+Glucose, mycelial phase.	5.6-21.4	$\underline{18.3}$-$\underline{82.1}$		Substrate	7
22		Mycelia	25	Mano	End	Mycelial phase.		3.2		Substrate	7
23		Mycelia	25	Mano	CHO	+Glucose, mycelial phase.		10.7-42.3		Substrate	7
24		Cell suspension	25	Mano	End	Yeast phase.	7.1-9.0			Substrate	7
25		Cell suspension	25	Mano	CHO	+Glucose, yeast phase.	7.8-39.0	$\underline{30.9}$-$\underline{142.0}$		Substrate	7
26		Cell suspension	25	Mano	CHO	+Glucose, yeast phase.		$\underline{21.9}$-$\underline{118.0}$		Substrate	7
27		Mycelia; cell suspension	25	Mano	CHO	+Glucose, mixed phase.	12.1-29.0	$\underline{52.3}$-$\underline{78.7}$		Substrate	7
28		Mycelia; cell suspension	25	Mano	CHO	+Glucose, mixed phase.		38.6-65.3		Substrate	7
29	M. stolonifer	Mycelia	20	Chem	CHO				1.53	Temperature	8
30		Mycelia	35	Chem	CHO				1.72	Temperature	8
31	Mycelium radicis atrovirens	Pellets[4, 5]	25		End	Unstarved; starved.	21-1.9			Substrate	9
32		Pellets[4, 5]	25		CHO	+Glucose.	8.7-10.9			Substrate	9
33		Pellets[4, 5]	25		CHO	+Succinate.	6.4-13.3			Substrate	9

34		Pellets[4,5]	25		CHO	+Fumarate.	7.1-16.5			Substrate	9
35		Pellets[4,5]	25		CHO	+Citrate.	10.0			Substrate	9
36	Phycomyces	Mycelia	20	Chem	CHO	1.5-3.5-7 da.		27-13-3		Age	10
37	blakesleeanus		Room	Chem	Com	On bread.			0.99-1.21	Substrate	11
38			Room	Chem	Com	On linseed.			0.66-0.75	Substrate	11
39	P. nitens	Mycelia	25	Mano	CHO	11γ Vit B_1/100 ml.	8.2-13.9			Accessory growth factors	12
40		Mycelia	19	Chem	Com				1.0		13
41	Rhizopus sp	Mycelia	28	Chem	CHO	4-8 da.		4.7			14
42	Zygorhyncus moelleri	Mycelia	25	Mano	End	pH 3.6;5.0;6.0;6.8;8.8.	6.3-8.6-9.4-6.4-10.3			pH	15
43		Mycelia	25	Mano	CHO	+Glucose, pH 3.6;5.0;6.0;6.8;8.0;8.8.	33.6-40.0-31.5-26.4-14.9-13.8			pH	15
44		Mycelia	25	Mano	CHO	+Glucose, NH_4Cl, pH 3.6;5.0;6.0;6.8;8.0;8.8.	51.9-56.9-48.2-53.1-27.6-23.2			pH	15
45		Mycelia	25	Mano	CHO	pH 6.8 + glucose, KNO_3; glucose, $NaNO_2$; glucose, NH_2OH; glucose, urea;glucose, aspartic;glucose,glutamic;glucose, asparagine.	28.1-29.0-23.2-44.6-40.6-49.9-47.2			Substrate; pH	15
46		Mycelia	25	Mano	CHO	pH 6.8, +sucrose; sucrose, NH_4Cl.	35.5-60.4			Substrate; pH	15
47		Mycelia	25	Mano	CHO	pH 6.8, +fructose; fructose, NH_4Cl.	11.0-12.7			Substrate; pH	15
48		Mycelia	25	Mano	CHO	pH 6.8, +acetate; acetate, NH_4Cl.	54.4-66.7			Substrate; pH	15
49		Mycelia	25	Mano	CHO	pH 6.8, +succinate; succinate, NH_4Cl.	29.8-31.2			Substrate; pH	15
						Ascomycetes					
50	Ashbya gossypii	Mycelia[4,5]	30	Mano	End	1;2;3 da.	19-11.8			Substrate; age	16
51		Mycelia[4,5]	30	Mano	CHO	+Glucose, 1;2;3 da.	32-20-12			Substrate; age	16
52		Mycelia[4,5]	30	Mano	CHO	+Sucrose, 1;2;3 da.	30-17-13			Substrate; age	16
53		Mycelia[4,5]	30	Mano	CHO	+Maltose, 1;2;3 da.	4-6-10			Substrate; age	16
54		Mycelia[4,5]	30	Mano	CHO	+Lactose, 1;2;3 da.	0-0-0				16
55		Mycelia[4,5]	30	Mano	Org	+Pyruvate, 1;2;3 da.	8-3-1			Substrate; age	16
56		Mycelia[4,5]	30	Mano	Org	+Acetate, 1;2;3 da.	6-9-7			Substrate; age	16
57		Mycelia[4,5]	30	Mano	Org	+Ethanol, 1;2;3 da.	12-8-3			Substrate; age	16
58	Chaetomium sp	Pellets	23-25	Chem	CHO				1.22		17
59	Cochliobolus miyabeanus	Mycelia		Mano	End	10; 15; 18; 35; 42 da.	3.8-4.3-3.1-1.5-1.7			Age	18
60	Erysiphe communis	Mycelia		Chem	Nat	Host (Torilis nodosa); host + fungus.			0.89-0.74	Parasitism	19
61	E. graminis tritici	Growing culture	22	Mano	Nat	Normal wheat leaf; leaf + fungus.	1.7[6]-6.0[6]			Parasitism	20
62		Growing culture	22	Mano	Nat	Wheat leaf epidermis; epidermis + fungus.	0.05[6]-1.3[6]			Parasitism	20

/1/ Mano = manometric; Chem = chemical; Volu = volumetric; Cond = conductometric; Pola = polarographic. /2/ End = endogenous; CHO = carbohydrates; Com = complex substrates; Nat = natural; Org = organic compounds. /3/ µl/mg wet wt/hr. /4/ Washed. /5/ Starved. /6/ µl/sq cm area/hr.

Values for rates of gaseous exchange are given in µl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate µl/mg/hr		R.Q. CO_2/O_2	Experimental Variable	Reference
							Q_{O_2}	Q_{CO_2}			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Ascomycetes (continued)					
63	Erysiphe graminis tritici (concluded)	Growing culture	22	Mano	Nat	Mildewed wheat leaf; leaf + $1x10^{-3}M\ Na_3N$.	6.0[6]-4.5[6]			Parasitism	20
64		Growing culture	22	Mano	Nat	Normal wheat leaf; leaf + fungus.		$\underline{1.8}$[6]-$\underline{2.7}$[6]		Parasitism	20
65	E. lamprocarpa	Mycelia		Chem	Nat	Host (Prasium majus); host + fungus.			0.82-0.78		19
66	Melanospora destruens	Mycelia	25	Mano	CHO	+1-11γ Vit B_1/100 ml.	3.0-6.4[3]		1.0	Accessory growth factors	12
67		Mycelia		Mano	CHO	+Glucose.	6			Substrate	21
68		Mycelia		Mano	CHO	+Fructose.	6			Substrate	21
69		Mycelia		Mano	CHO	+Sucrose.	10			Substrate	21
70		Mycelia		Mano	CHO	+Maltose.	1.1			Substrate	21
71		Mycelia		Mano	CHO	+Lactose.	15			Substrate	21
72		Mycelia		Mano	CHO	+Raffinose.	11			Substrate	21
73		Mycelia		Mano	CHO	+Starch.	13			Substrate	21
74		Mycelia		Mano	CHO	+Glycogen.	7			Substrate	21
75	Neurospora crassa	Mycelia		Mano	CHO	Endogenous.	16-55			Inhibitors	22
76		Mycelia		Mano	CHO	+0.1% sulfanilamide.	12-21			Inhibitors	22
77		Mycelia	30	Mano	Org	Endogenous.	11-38	$\underline{0-5}$		Substrate	23
78		Mycelia	30	Mano	Org	+Pyruvate.	26-44	$\underline{6}$		Substrate	23
79		Mycelia	30	Mano	Org	4 mutant strains.	11-44			Strains	23
80		Mycelia		Mano	CHO	Starved, p-aminobenzoic-less mutant.	11.7-31.2			Mutant	24
81		Mycelia		Mano	CHO	Starved, pantothenic-less mutant.	15.1-26.8			Mutant	24
82		Mycelia[5]		Mano	CHO	-;+p-Aminobenzoic acid.	24.0-43.1			Accessory growth factors; mutants or strains	24
83		Mycelia[5]		Mano	CHO	-;+Pantothenic acid.	21.8-27.0			Accessory growth factors; mutants or strains	24
84	N. sitophila	Mycelia		Mano	CHO	Starved, pyridoxine-less mutant.	18.7-35.6			Mutant	24
85		Mycelia[5]		Mano	CHO	-;+Pyridoxine.	19.2-26.4			Accessory growth factors; mutants or strains	24
86	N. tetrasperma	Ascospores	25	Mano	End	Dormant.	0.25-0.59	$\underline{<0.03}$		Age	25
87		Ascospores	25	Mano	End	Activated by heat.	4.5-10.9	$\underline{5.0-10.9}$		Time after activation	25
88		Ascospores	25	Mano	End	Germinating.	10-20			Time after activation	25

89		Ascospores	26	Mano	End	-;+10^{-5}M, 10^{-4}M; 10^{-3}M;10^{-2}M; $5x10^{-2}$M furfurol (determinations after 290-350 min).	0.5-1.3-3.9-7.8-7.1-1.3				26
90	Neurospora sp	Mycelia[5]		Mano	CHO		15.1-56.0				24
91		Mycelia[5]		Mano	CHO	Starved, thiamine-less mutant.	16.0-35.6			Mutant	24
92		Mycelia[5]		Mano	CHO	Starved, nicotinic-less mutant.	25.0-41.0			Mutant	24
93	Saccharomyces cerevisiae R	Cell suspension		Mano	CHO	No stored reserves.	83-109	370-432-278-299		Organic nutrition	27
94		Cell suspension		Mano	CHO	Fat reserves.	76	249-322		Organic nutrition	27
95		Cell suspension		Mano	CHO	Glycogen reserves.	0	63-116		Organic nutrition	27
96	S. cerevisiae U	Cell suspension		Mano	CHO	No stored reserves.	10-137	160-348-276-284		Organic nutrition	27
97		Cell suspension		Mano	CHO	Fat reserves.	125	151-261		Organic nutrition	27
98		Cell suspension		Mano	CHO	Glycogen reserves.	47	82-83		Organic nutrition	27
99	S. cerevisiae C x S. globosus (GIl hybrid)	Cell suspension		Mano	CHO	No stored reserves.	60-74	377-421-241-308		Organic nutrition	27
100		Cell suspension		Mano	CHO	Fat reserves.	127	500-377		Organic nutrition	27
101		Cell suspension		Mano	CHO	Glycogen reserves.	52	156-117		Organic nutrition	27
102	S. cerevisiae, bakers	Cell suspension	28	Mano	CHO		90	10-250			28
103		Cell suspension[4]	22-25	Mano	CHO	Endogenous;+glucose.	4.8[3]-3.9[3]			Substrate	29
104		Cell suspension[4]	22-25	Mano	CHO	+Glucose.		37.8[3]-46.2[3]		Substrate	29
105		Cell suspension	30	Cond	Com	0.5;1.5;8 hr.	55[3]-63[3]-42[3]			Age	30
106		Cell suspension	25	Mano	Org	Warburg apparatus.	12.3[3]			Method	31
107		Cell suspension	25	Pola	Org	Dropping mercury electrode.	12.9[3]			Method	31
108		Cell suspension		Mano	CHO		113	88-280			32
109		Cell suspension[4]	30	Mano	CHO	+Glucose.	29[3]	79[3]		Inhibitors	33
110		Cell suspension[4]	30	Mano	CHO	+Glucose, +$5x10^{-3}$M methanol.	26[3]	79[3]		Inhibitors	33
111		Cell suspension[4]	30	Mano	CHO	+Glucose, +$5x10^{-3}$M formaldehyde.	10[3]	34[3]		Inhibitors	33
112		Cell suspension[4]	30	Mano	CHO	+Glucose, +$5x10^{-3}$M formic acid.	28[3]	87[3]		Inhibitors	33
113		Cell suspension[4,5]	28	Mano	Org	+Pyruvate, pH 2.8-9.4.	23-0		0.91-0.98	pH	34
114		Cell suspension[4]	37	Mano	End	Endogenous; +$5x10^{-4}$M ricinoleic acid.	31-85				35
115		Cell suspension[4]	37	Mano	Org	Endogenous; +$5.8x10^{-4}$M decoic acid.			0.94-0.80		35
116		Cell suspension[4]	37	Mano	Org	Endogenous; +$4.3x10^{-3}$M hexoic acid.			0.94-0.73		35
117		Cell suspension[4,5]	26	Mano	CHO	Control, ultraviolet treated.			0.88-0.80	Radiation	36
118		Cell suspension[4]	30	Mano	Com	Control.	5.5	55.3			37
119		Cell suspension[4]	30	Mano	Com	+10 γ-pantothenate.	8.4	84.0		Accessory growth factors	37

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Values for rates of gaseous exchange are given in µl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate µl/mg/hr Q_{O_2}	Respiration Rate µl/mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Ascomycetes (continued)					
120	Saccharomyces cerevisiae, bakers (concluded)	Cell suspension[4]	30	Mano	Com	+0.1 γ-thiamine.	5.3	60.0		Accessory growth factors	37
121		Cell suspension[4]	30	Mano	Com	+0.1 γ-pantothenate + 0.1 γ-thiamine.	6.3	76.2		Accessory growth factors	37
122		Cell suspension[4]	30	Mano	Com	+10 mg liver extract.	5.5	93.0		Accessory growth factors	37
123		Cell suspension	30	Mano	CHO	-Biotin.	2.8-9.3			Accessory growth factors	38
124		Cell suspension	30	Mano	CHO	Biotin rich.	70-75			Accessory growth factors	38
125		Cell suspension	27	Mano			54				39
126		Cell suspension	27	Mano			27	48-$\underline{209}$			39
127		Cell suspension	30	Mano	CHO		30	39-$\underline{249}$			40
128		Cell suspension[4,5]	20	Mano	End	0-4 hr in buffer.	3.2[3]-0.9[3]			Age	41
129		Cell suspension[4,5]	20	Mano	End	0-3 hr in buffer.			0.6-1.0	Age	41
130		Cell suspension[4,5]	20	Mano	CHO	$+10^{-3}$;$5x10^{-2}$;10^{-1}M glucose.	55[3]-16.0[3]-13.5[3]			Organic nutrition	41
131		Cell suspension[4,5]	20	Mano	CHO	$+10^{-3}$;10^{-2};10^{-1}M glucose.		5.5[3]-23.0[3]-27.0[3]		Organic nutrition	41
132		Cell suspension[4]	20	Mano	Org	$+5x10^{-4}$M ethanol at 0;2;3 hr.	8.0[3]-2.0[3]-1.2[3]			Organic nutrition	41
133		Cell suspension[4]	20	Mano	Org	$+10^{-4}$M ethanol at 0;2;3 hr.	8.0[3]-2.5[3]-2.0[3]			Organic nutrition	41
134		Cell suspension[4]	20	Mano	Org	$+5x10^{-3}$M ethanol at 0;2;3 hr.	8.0[3]-11.0[3]-2.5[3]			Organic nutrition	41
135		Cell suspension[4]	20	Mano	Org	$+10^{-2}$M ethanol at 0;3;5 hr.	8.0[3]-13.0[3]-2.0[3]			Organic nutrition	41
136		Cell suspension[4]	30	Mano	CHO	±Glutathione;±cysteine.	1.1	23		Accessory growth factors	42
137		Cell suspension[4]	30	Mano	CHO	±Glutathione;±cysteine.	3-6.4			Accessory growth factors	42
138	S. cerevisiae, bottom	Cell suspension	28	Mano	CHO		10	150-$\underline{170}$			28
139		Cell suspension	25	Mano	CHO	Endogenous; +glucose.	11.8-33.7			Substrate	43
140		Cell suspension	25	Mano	End	$+2x10^{-5}$; $2x10^{-4}$; $2x10^{-3}$M KCN.	11.8-7.5-1.1			Inhibitors	43
141		Cell suspension	25	Mano	CHO	+Glucose; $-2x10^{-5}$; $2x10^{-4}$; $2x10^{-3}$M KCN.	27.3-18.1-2.2			Inhibitors	43
142	S. cerevisiae 812	Cell suspension	30	Mano	CHO	Endogenous; +glucose.	28.1-61.0	$\underline{0.4}$		Substrate	44

143	S. cerevisiae, brewers	Cell suspension[4]	22-25	Mano	CHO	Endogenous; +glucose.	4.2[3]-19.5[3]	8.7-58.0		Substrate	29
144		Cell suspension[4]	Room	Volu	End	-; +$5x10^{-2}$M fluoride.		1.8[3]-0[3]		Inhibitors	45
145		Cell suspension[4]	Room	Volu	CHO	-; +$5x10^{-2}$M fluoride, +fructose.		21.6[3]-1.4[3]		Inhibitors	45
146		Cell suspension[4]	Room	Volu	CHO	-; +$5x10^{-2}$M fluoride, +glucose.		20.4[3]-0[3]		Inhibitors	45
147		Cell suspension[4]	Room	Volu	CHO	+Mannose; -, +$5x10^{-2}$M fluoride.		18.0[3]-0[3]		Inhibitors	45
148	S. cerevisiae, top	Cell suspension	27	Mano		±Glutathione; ±cysteine	28	207-216			39
149		Cell suspension	30	Volu	CHO	+0;$5x10^{-2}$N phenol; +glucose.		47[3]-43[3]-15[3]		Inhibitors	46
150		Cell suspension	30	Volu	Com	+0; $5x10^{-2}$N phenol; +peptone.		73[3]-68[3]-14[3]		Inhibitors	46
151	S. cerevisiae, wine	Cell suspension	27	Mano			57	177			39
152	S. cerevisiae	Cell suspension[4]	20	Mano	Org	+$5x10^{-2}$M ethanol at 0;3;6 hr.	8.0[3]-9.0[3]-10.0[3]			Organic nutrition	41
153		Cell suspension[4]	20	Mano	Org	+$5x10^{-1}$M ethanol at 0;3;6 hr.	8.0[3]-8.5[3]-9.0[3]			Organic nutrition	41
154	S. italicus	Cell suspension[4]	30	Mano	End			0			40
155	S. ludwigii	Cell suspension	30	Mano	CHO	Endogenous; + glucose.	38-144	0.9		Substrate	44
156		Cell suspension	25	Volu	CHO	+Glucose.		140		Substrate	47
157		Cell suspension	25	Volu	Org	+Dioxyacetone.	56-64			Substrate	47
158	S. wanching	Cell suspension	25	Mano	End		14[7]	0[7]		Substrate	48
159		Cell suspension	25	Mano	CHO	+Fructose.	36[7]	17[7]		Substrate	48
160		Cell suspension	25	Mano	CHO	+Galactose.	24[7]	2[7]		Substrate	48
161		Cell suspension	25	Mano	CHO	+Glucose; mannose.	40[7]-39[7]	40[7]-40[7]		Substrate	48
162		Cell suspension	25	Mano	CHO	+Maltose.	51[7]	45[7]		Substrate	48
163		Cell suspension	25	Mano	CHO	+Lactose.	36[7]	3[7]		Substrate	48
164		Cell suspension	25	Mano	CHO	+Sucrose.	42[7]	45[7]		Substrate	48
165		Cell suspension	25	Mano	CHO	+Xylose.	18[7]	8[7]		Substrate	48
166		Cell suspension	25	Mano	CHO	+Arabinose.	25[7]	5[7]		Substrate	48
167		Cell suspension	25	Mano	Org	+Succinate; oxalate; citrate.	14[7]-14[7]-14[7]	0[7]-0[7]-0[7]		Substrate	48
168		Cell suspension	25	Mano	Org	+Glycerol; formate; propionate; butyrate; valerate.	18[7]-14[7]-16[7]-12[7]-19[7]	0[7]-0[7]-0[7]-0[7]-0[7]		Substrate	48
169		Cell suspension	25	Mano	Org	+Acetate; lactate.	33[7]-28[7]	0[7]-0[7]		Substrate	48
170		Cell suspension	25	Mano	Org	+Pyruvate.	42[7]	18[7]		Substrate	48
171		Cell suspension	20	Mano	CHO	+Acetate, pH 5.4; 6.8.	46[7]-33[7]			pH	49
172		Cell suspension	20	Mano	CHO	+Lactate, pH 5.1; 6.8.	23[7]-28[7]			pH	49
173		Cell suspension	20	Mano	CHO	+Pyruvate, pH 4.1; 6.8.	40[7]-42[7]			pH	49
174		Cell suspension	20	Mano	CHO	+Glucose-phosphate, pH 4.5; 6.8.	42[7]-40[7]			pH	49
175	Schizosaccharomyces octosporus	Cell suspension	30	Mano	CHO	Endogenous; +glucose.	21-90	0.1			44
176	S. pombe	Cell suspension	30	Volu	CHO	+Glucose.	0.235[3]				50
177		Cell suspension	30	Mano	CHO	Endogenous, +glucose.	17.9-36.4	0.4			44
178	Sclerotinia sp	Pellets	23-25	Chem	CHO				1.15		17
179	Sordaria fimicola	Mycelia	26	Mano	End		1.28				51
180	Sordaria sp	Pellets	23-25	Chem	CHO				1.56		17

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Values for rates of gaseous exchange are given in μl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate μl/mg/hr Q_{O_2}	Respiration Rate μl/mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Ascomycetes (concluded)					
181	Taphrina deformans	Mycelia		Chem	Nat	Host (Amygdalus communis); host + fungus.			1.04;0.84	Parasitism	19
182	Thermoascus aurantiacus	Mycelia	27	Chem	Com				0.91-0.94	Temperature	52
183		Mycelia	45	Chem	Com				1.04-1.07	Temperature	52
184		Mycelia	45	Chem	End				0.95-0.98	Temperature	52
185		Mycelia	45	Chem	End	3;20 hr after 12 hr in N_2.			5.88-1.00	Temperature	52
186	Zygosaccharomyces acidifaciens	Cell suspension[4]	28	Mano	End	24;48;72 hr.	16-7-7			Substrate; age	53
187		Cell suspension[4]	28	Mano	CHO	+Glucose at 24;48;72 hr.	60-35-35			Substrate; age	53
188		Cell suspension[4]	28	Mano	End	72-144 hr; cells grown anaerobically.	13-2			Substrate; growth or age	53
189		Cell suspension[4]	28	Mano	CHO	+Glucose for 72-144 hr; cells grown anaerobically.	17-11			Substrate; growth or age	53
190		Cell suspension[4]	28	Mano	CHO	+0.01;0.04;0.2% glucose.	32-38-67			Substrate; age	54
191		Cell suspension[4]	28	Mano	CHO	+Glucose for 1-2 hr.		$\underline{59}$-$\underline{53}$		Substrate; age	54
192		Cell suspension[4]	28	Mano	End	+Glucose for 1-4 hr.			2.13-1.55	Substrate; age	54
193		Cell suspension[4]	28	Mano	End	4 hr.			1.14	Substrate; age	54
						Basidiomycetes					
194	Agaricus bisporus (A. campestris; Psalliota campestris)	Sporophores		Chem					0.54-0.59		13
195		Sporophores	28	Mano	End				1.07		55
196		Growing culture		Mano			1.9		0.87		56
197		Growing culture	25	Volu			1.9-2.9	2.3-4.0	0.70-0.90		57
198	Auricularia mesenterica (Thelephora tremelloides)	Mycelia		Chem					0.5-0.6		13
199	Boletus luridus	Sporophores	17	Chem	End			1.5			58
200	Bovista tunicata	Sporophores	18	Chem	End			1.78[3]-1.07[3] $\underline{8.7}$[3]-$\underline{5.6}$[3]			59
201	Bterkandera fumosa (Polyporus imberbis)	Sporophores	28	Mano	End				0.89		55
202	Coprinus comatus	Sporophores	17	Chem	End			2.7			58
203	C. micaceus	Sporophores	17	Chem	End			4.5			58
204	Coriolus versicolor (Polyporus versicolor; Polystictus versicolor)	Mycelia		Chem	Com	17.5°C;25.5°C;33.5°C.		8.4[7]-12.2[7]-14.6[7]		Temperature	60
205		Mycelia		Chem					0.56-0.75		13
206		Mycelia	17.5	Chem	Com	+2;21;100% O_2.		3.6[7]-8.5[7]-10.4[7]		O_2 pressure	61

207		Mycelia	29.5	Chem	Com	+2;21;100% O_2.		7.4[7]-14.2[7]-17.2[7]		O_2 pressure	61
208		Sporophores	17	Chem	End			0.3			58
209		Sporophores	28	Mano	End				0.91		55
210	Cystopus candidus	Mycelia		Chem	Nat	Host (Isatis djurdjurae); host + fungus.			0.93-0.95	Parasitism	19
211	Daedalea quercina	Mycelia		Chem					0.7-0.8		13
212	Exidia glandulosa	Mycelia		Chem					0.7		13
213	Flammulina velutipes	Sporophores		Chem					0.6		13
214	(Agaricus velutipes; Collybia velutipes)	Sporophores	28	Mano	End				0.88		55
215	Gymnopilus sapineus (Flammula sapinea)	Sporophores	20	Chem	End		0.66[3]				59
216	Lactarius serifluus	Sporophores	17	Chem	End			2.7			58
217	Marasmius conigenus	Sporophores	17	Chem	End			3.4			58
218	Melampsora pulcherrinum	Mycelia		Chem	Nat	Host (Mercurialis ambigua); host + fungus.			0.97-0.96	Parasitism	19
219	Merulius lachrymans	Sporophores	17	Chem	End			1.0			58
220	Naematoloma fasciculare (Agaricus fascicularis)	Sporophores	17	Chem	End			0.73[3]-0.41[3]			59
221	Phragmidium rosae sempervirentis	Mycelia		Chem	Nat	Host (Rosa sempervirens); host + fungus.			0.92-0.93	Parasitism	19
222	Polyporus squamosus	Growing culture		Mano			3.0		0.85		56
223		Sporophores	17	Chem	End			1.0			58
224	Puccinia graminis tritici	Uredospore	30	Mano	End	PO_4 buffer, pH 6.5, ungerminated.	1.6[3]	1.1[3]	0.65	Activation	63
225		Uredospore	30	Mano	End	Germinated.	1.4[3]	1.0[3]	0.70		63
226	P. kundmaniae	Mycelia		Chem	Nat	Host (Kundmania sicula); host + fungus.			0.95-0.87	Parasitism	19
227	P. malvacearum	Mycelia		Chem	Nat	Host (Malva nicaeensis); host + fungus.			0.79-0.95	Parasitism	19
228	P. pruni	Mycelia		Chem	Nat	Host (Anemone coronaria); host + fungus.			1.06-0.82	Parasitism	19
229	P. smyrnii	Mycelia		Chem	Nat	Host (Smyrnium elustrum); host + fungus.			0.71-0.75	Parasitism	19
230	Stereum hirsutum	Sporophores	28	Mano	End				0.89		55
231	Urocystis anemones	Mycelia		Chem	Nat	Host (Ranunculus macrophyllus); host + fungus.			0.80-0.84	Parasitism	19
232	Ustilago avenae	Pellets	23-25	Chem	CHO				1.01		17
233	U. maydis	Pellets	23-25	Chem	CHO				1.17		17
234	U. sphaerogena	Sporidia[4]		Mano	CHO			0			64
235		Sporidia[4]		Mano	End		75			Substrate	64
236		Sporidia[4]		Mano	CHO	+Sugars.	375			Substrate	64
						Fungi Imperfecti					
237	Acrostalagmus	Mycelia	35	Chem	Org, CHO				0.96	Temperature	8
238	cinnabarinus	Mycelia	15	Chem	Org, CHO				1.02	Temperature	8
239	Alternaria sp	Pellets	23-25	Chem	CHO				1.26-1.31	Mutants or strains	17

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	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate µl/mg/hr Q_{O_2}	Respiration Rate µl/mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Fungi Imperfecti (continued)					
240	Aspergillus albus	Pellets	23-25	Chem	CHO				1.16		65
241	A. aureus	Mycelia	30	Volu	CHO	4-6 da.	11-12			Age	66
242		Mycelia	15-25	Volu	CHO			3.1			67
243	A. awamori	Mycelia	30	Volu	CHO	2-4 da.	28-24			Age	66
244		Mycelia	15-25	Volu	CHO			8.3			67
245	A. candidus	Pellets	23-25	Chem	CHO				1.11-1.58	Mutants or strains	65
246		Mycelia	15-25	Volu	CHO			14.1			67
247	A. carbonarius	Pellets	23-25	Chem	CHO				1.68		65
248	A. clavatus	Pellets	23-25	Chem	CHO	4 strains.			1.63-2.48	Strains	65
249		Mycelia	30	Volu	CHO	4-6 da.	11-9			Age	66
250		Mycelia	15-25	Volu	CHO			12.4			67
251		Mycelia	15-25	Volu	Com			44.3			67
252	A. conicus	Pellets	23-25	Chem	CHO				1.21		65
253	A. cyaneus	Pellets	23-25	Chem	CHO				1.22		65
254	A. disjunctus	Pellets	23-25	Chem	CHO				1.08		65
255	A. effusus	Pellets	23-25	Chem	CHO				1.36		65
256	A. elegans	Pellets	23-25	Chem	CHO	2 strains.			1.58-1.81	Strains	65
257	A. ferrugineus	Pellets	23-25	Chem	CHO				1.01		65
258	A. ficuum	Pellets	23-25	Chem	CHO				1.96		65
259	A. fischeri	Pellets	23-25	Chem	CHO	2 strains.			1.03-1.17	Strains	65
260	A. flavipes	Pellets	23-25	Chem	CHO	2 strains.			1.03-1.20	Strains	65
261	A. flavus (A. soya)	Pellets	23-25	Chem	CHO	2 strains.			2.21-2.56	Strains	65
262		Mycelia	30	Volu	CHO	4-6 da.	6-7			Age	66
263		Mycelia	30	Volu	CHO	4-6 da.	11-9			Age	66
264		Mycelia	15-25	Volu	CHO			16.6			67
265	A. flavus var.	Mycelia	30	Volu	CHO	3-5 da.	27-18			Age	66
266	A. fumaricus	Pellets	23-25	Chem	CHO				1.05		65
267	A. fumigatus	Mycelia	30	Volu	CHO	4-6 da.	17-15			Age	66
268		Mycelia	15-25	Volu	CHO			0			67
269		Pellets	23-25	Chem	CHO	3 strains.			1.11-1.15	Strains	65
270	A. fuscus	Pellets	23-25	Chem	CHO				1.76		65
271	A. giganteus	Pellets	23-25	Chem	CHO	2 strains.			1.49-1.84	Strains	65
272		Mycelia	30	Volu	CHO	4-6 da.	11-14			Age	66
273		Mycelia	15-25	Volu	CHO			0			67
274	A. glaucus	Pellets	23-25	Chem	CHO	2 strains.			0.89-1.02	Strains	65
275		Mycelia	30	Volu	CHO	3-5 da.	21-20			Age	66
276		Mycelia	15-25	Volu	Com,CHO			0			67
277	A. gymnosardae	Mycelia	30	Volu	CHO	2-4 da.	17-8			Age	66
278		Mycelia	15-25	Volu	CHO			14.5			67
279		Mycelia	15-25	Volu	Com			0			67
280	A. helvus	Pellets	23-25	Chem	CHO				1.94		65

281	A. itaconicus	Mycelia	30	Volu	CHO	4-6 da.	16-12			Age	66
282	A. japonicus	Mycelia	15-25	Volu	CHO			11.1			67
283	A. luchuensis	Pellets	23-25	Chem	CHO	3 strains.			1.52-1.87	Strains	65
284		Mycelia	15-25	Volu	CHO			6.1			67
285		Mycelia	15-25	Volu	Com			<1			67
286		Conidia	30	Mano	CHO	+Raffinose, pH 4;6;8.	3.9-4.5-3.7			pH	68
287		Conidia	30	Mano	CHO	+Sucrose, pH 4;6;8.	5.0-7.0-5.1			pH	68
288		Conidia	30	Mano	CHO	+Furanose, pH 4;6;8.	3.9-3.8-4.1			pH	68
289		Conidia	30	Mano	CHO	+Maltose, pH 4;6;8.	2.6-3.3-3.5			pH	68
290		Conidia	30	Mano	CHO	+Cellobiose, pH 4;6;8.	8.2-8.8-4.8			pH	68
291		Conidia	30	Mano	CHO	+Trehalose, pH 4;6;8.	8.1-6.8-3.3			pH	68
292		Conidia	30	Mano	CHO	+Glucose, pH 4;6;8.	9.6-9.7-10.8			pH	68
293		Conidia	30	Mano	CHO	+Fructose, pH 4;6;8.	4.8-5.0-3.6			pH	68
294		Conidia	30	Mano	CHO	Endogenous, pH 4;6;8.	2.0-2.3-2.8			pH	68
295	A. mannitus	Mycelia	15-25	Volu	CHO			0			67
296	A. medius	Pellets	23-25	Chem	CHO				0.99		65
297	A. melleus	Mycelia	30	Volu	CHO	4-6 da.	12-11			Age	66
298		Mycelia	15-25	Volu	CHO			<1			67
299	A. minimus	Pellets	23-25	Chem	CHO	2 strains.			1.15-1.19	Strains	65
300		Mycelia	15-25	Volu	CHO			0			67
301	A. mollis	Pellets	23-25	Chem	CHO				0.98		65
302	A. nidulans	Pellets	23-25	Chem	CHO	7 strains.			1.22-1.64	Strains	65
303		Mycelia	15-25	Volu	CHO			0			67
304	A. niger	Mycelia	30	Volu	CHO	2-4 da.	15-12			Age	66
305		Mycelia	15-25	Volu	CHO			2.9			67
306		Mycelia	24-25	Chem	Org,CHO	+1;10;17% glucose.			0.89-1.30-0.47	Substrate	69
307		Mycelia	24-25	Chem	Org,CHO	+1;10;25% sucrose.			0.85-1.04-0.73	Substrate	69
308		Mycelia	24-25	Chem	Org,CHO	+5;10% mannitol.			0.47-0.66	Substrate	69
309		Mycelia	24-25	Chem	Org,CHO	+1.5;7.0% tartrate.			1.59-1.57	Substrate	69
310		Mycelia	20	Chem	Org,CHO	+10% sucrose.			1.05-1.09	Substrate	70
311		Mycelia	20	Chem	Org,CHO	+10% glucose.			1.17-1.19	Substrate	70
312		Mycelia	20	Chem	Org,CHO	+10% raffinose.			0.90-0.93	Substrate	70
313		Mycelia	30	Mano	End	+0.02%;0.2% K_2HPO_4.	6.2-11.4			Substrate	71
314		Mycelia	3-5	Chem	End	Starved 1 da.			0.36	Temperature	8
315		Mycelia	19-20	Chem	End	Starved 1 da.			0.66	Temperature	8
316		Mycelia	35	Chem	End	Starved 1 da.			1.06-1.19	Temperature	8
317		Mycelia	21	Chem	End	Starved 3 da.			0.62	Temperature	8
318		Mycelia	36	Chem	End	Starved 3 da.			0.87	Temperature	8
319		Mycelia	22	Chem	End	Starved 5 da.			0.51	Temperature	8
320		Mycelia	36	Chem	End	Starved 5 da.			0.57	Temperature	8
321		Mycelia	19	Chem	CHO	+Glucose.			0.98	Substrate; temperature	8
322		Mycelia	22	Chem	CHO	+Glucose.			1.00	Substrate; temperature	8
323		Mycelia	35	Chem	CHO	+Glucose.			1.30	Substrate; temperature	8
324		Mycelia	36	Chem	CHO	+Glucose.			1.32	Substrate; temperature	8

/1/ Mano = manometric; Chem = chemical; Volu = volumetric; Cond = conductometric; Pola = polarographic. /2/ End = endogenous; CHO = carbohydrates; Com = complex substrates; Nat = natural; Org = organic compounds.

Values for rates of gaseous exchange are given in µl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate µl/mg/hr Q_{O_2}	Respiration Rate µl/mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Fungi Imperfecti (continued)					
325	Aspergillus niger (concluded)	Mycelia	18	Chem	CHO	+Sucrose.			0.91	Substrate; temperature	8
326		Mycelia	35	Chem	CHO	+Sucrose.			1.22	Substrate; temperature	8
327		Mycelia	22	Chem	Org	+Tartrate.			1.40-2.11	Substrate; temperature	8
328		Mycelia	36	Chem	Org	+Tartrate.			1.35-2.03	Substrate; temperature	8
329		Mycelia	22	Chem	Org	+Glycerol.			0.50-0.54	Substrate; temperature	8
330		Mycelia	36	Chem	Org	+Glycerol.			0.82-0.86	Substrate; temperature	8
331		Mycelia	3-5	Chem	Org	+Mannitol.			0.73	Substrate; temperature	8
332		Mycelia	35	Chem	Org	+Mannitol.			1.20	Substrate; temperature	8
333		Mycelia	30	Mano	CHO	4 da, +glucose;glucose iodoacetate; glucose fluoride; glucose azide;glucose cyanide.	12.7-1.6-3.6-0.5-5.8-1.3-2.8-1.5			Substrate; age	71
334		Mycelia	32	Chem	CHO	13;16;20 mg dry wt/ml.	29-22-18			Method	72
335		Mycelia	35	Chem	CHO	Acid; neutral;alkaline.			1.00-0.90-0.99	pH	73
336		Mycelia		Chem	CHO	+0.5% total salts.			0.73-0.87	Inorganic nutrition	74
337		Mycelia	30	Mano	CHO		12.7				71
338		Mycelia	20	Chem	End	2;5;9 da.	5.2-1.6-0.6			Age	75
339		Mycelia	20	Chem	CHO	2;5;9 da.	12.2-2.9-1.1			Age	75
340		Mycelia	20	Chem	CHO	+Sucrose, 7;26 da.			1.05-0.91	Age	76
341		Mycelia	20	Chem	Org	+Tartrate, 10;23 da.			2.54-1.00	Age	76
342		Mycelia	20	Chem	Org	+Malate, 9;31 da.			1.76-0.84	Age	76
343		Mycelia	20	Chem	Org	+Citrate, 34;54 da.			1.68-0.91	Temperature; age	76
344		Mycelia	33	Chem	Org	+Citrate, 8;21 da.			1.54-0.78	Temperature; age	76
345		Mycelia	14-33	Chem	Com	+Tannin, 2;17 da.			1.13-0.87	Temperature; age	76
346		Mycelia	15	Chem	Com			7-$\underline{2}$			77
347		Pellets	23-25	Chem	CHO	4 strains.			1.24-1.93	Strains	65
348		Mycelia[4]	23-25	Chem	Org	+Citrate, malate, glycolate, oxalate.		0[7]		Substrate	78
349		Mycelia[4]	23	Chem	End	0-500 hr.		$\underline{100}$[7]-$\underline{10}$[7]		Age	78
350		Mycelia[4]	23	Chem	Org, CHO	Endogenous; +glucose; +citrate.			1.0->1.0-1.75	Substrate	78

351		Conidia	30	Mano	CHO	Glucose, ethanolamine buffer, 0-4; 4-6; 6-8 hr.	0.3-1.0-3.0			Age	79
352	A. niger mut. cinnamomeus	Pellets	23-25	Chem	CHO				0.99		65
353	A. niger citricus	Pellets	23-25	Chem	CHO				1.45		65
354	A. ochraceus	Pellets	23-25	Chem	CHO	3 strains.			1.45-1.60	Strains	65
355	(A. oniki)	Mycelia	30	Volu	CHO	4-6 da.	15-14			Age	66
356		Mycelia	15-25	Volu	CHO			<1			67
357		Mycelia	30	Volu	CHO	3-5 da.	16-15			Age	66
358		Mycelia	15-25	Volu	CHO			<1			67
359	A. okazakii	Pellets	23-25	Chem	CHO				1.20		65
360	A. oryzae	Mycelia		Mano	CHO	0;33;67% O_2.	0-15.3-31.7			O_2 pressure	80
361		Mycelia		Mano	CHO	17;50;83% O_2.	8.6-5.9-0.7			O_2 pressure	80
362		Mycelia		Mano	CHO			9.3-10.8			80
363		Mycelia		Mano	CHO	O_2/CO_2=50/0;50/20; 50/50.	32-40-40			Inhibitors	80
364		Mycelia		Mano	CHO	N_2;CO(dark);CO(light); (gas/O_2:95/5).	49-26-30	5.6-9.7-10.4		Inhibitors	80
365		Mycelia		Mano	CHO	0;10^{-3};10^{-2}M KCN surface culture.	41-36-12			Inhibitors	80
366		Mycelia		Mano	CHO	0;10^{-3};2x10^{-3}M KCN submerged culture.	73-16-11			Inhibitors	80
367		Mycelia	30	Volu	CHO	2;3;6 da.	26-30-20			Age	66
368		Mycelia	15-25	Volu	CHO			4.2-13.4			67
369		Mycelia	25	Volu	Org	End;+M/20 oxalate.	4.6-3.9			Substrate	81
370		Pellets	23-25	Chem	CHO				2.05		65
371		Mycelia[5]	30	Chem	CHO	+2x10^{-3};2x10^{-2}; 2x10^{-1} M sucrose.	5.5-13-24			Substrate	82
372		Mycelia[5]	30	Chem	End				0.96	Substrate	82
373		Mycelia[5]	30	Chem	CHO	+Sucrose.			1.13	Substrate	82
374		Mycelia[5]	30	Chem	Org	+Gluconate.			1.11	Substrate	82
375		Mycelia[5]	30	Chem	Org	+Mannitol.			0.96	Substrate	82
376		Mycelia[5]	30	Chem	Org	+Ethanol.			0.67	Substrate	82
377		Mycelia[5]	30	Chem	Org	+Glycerol.			0.86	Substrate	82
378		Conidia	30	Mano	CHO	Mineral med., germinating, 0;2;3 hr.	1.26-2.40-2.17			Age	83
379	Aspergillus ostianus	Pellets	23-25	Chem	CHO	2 strains.			1.42-1.65	Strains	65
380		Mycelia	30	Volu	CHO	4-6 da.	11-11			Age	66
381		Mycelia	15-25	Volu	CHO			1			67
382	A. parasiticus	Pellets	23-25	Chem	CHO				1.50		65
383	A. pseudo-glauca (A. novus)	Pellets	23-25	Chem	CHO				1.03		65
384	A. pulverulentus	Pellets	23-25	Chem	CHO				1.57		65
385	A. repens	Pellets	23-25	Chem	CHO	2 strains.			0.91-1.09	Strains	65
386		Mycelia	30	Volu	CHO	3-5 da.	13-7			Age	66
387	A. scheelei	Pellets	23-25	Chem	CHO				1.09		65
388	A. sydowi	Pellets	23-25	Chem	CHO	5 strains.			1.12-1.34	Strains	65
389	A. tamarii	Pellets	23-25	Chem	CHO	2 strains.			1.41-1.42	Strains	65
390	A. terreus	Pellets	23-25	Chem	CHO	2 strains.			1.48-1.75	Strains	65

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Values for rates of gaseous exchange are given in µl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate µl/mg/hr Q_{O_2}	Respiration Rate µl/mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Fungi Imperfecti (continued)					
391	Aspergillus terricola var. americana	Pellets	23-25	Chem	CHO	2 strains.			1.74-3.04	Strains	65
392	A. versicolor	Pellets	23-25	Chem	CHO	8 strains.			1.14-1.42	Strains	65
393	A. violaceo-fuscus	Pellets	23-25	Chem	CHO				1.64		65
394	A. wentii	Pellets	23-25	Chem	CHO	3 strains.			1.03-1.19	Strains	65
395		Mycelia		Volu	CHO	3-5 da.	15-17			Age	66
396		Mycelia	15-25	Volu	CHO			<1		Growth or age	67
397		Mycelia	15-25	Volu	Com			0			67
398	Aspergillus sp	Pellets	23-25	Chem	CHO	8 strains.			1.13-1.42	Strains	65
399	Blastomyces brasiliensis	Cell suspension[4,5]	20	Mano	CHO	Mycelial phase.	2.4				84
400		Cell suspension[4,5]	20	Mano	CHO	Yeast phase.	14.2				84
401	B. dermatitidis	Cell suspension[4,5]		Mano	End	3°C;41°C;45°C.	1.3-13.3-10.3			Temperature	84
402		Cell suspension[4,5]	37	Mano	Org	+Acetate; endogenous.	39-7.5			Substrate	84
403		Cell suspension[4]	37	Mano	End	Endogenous, pH 2;6;8.	0.5[8]-12.0[8]-11.0[8]			pH	85
404		Cell suspension[4]	37	Mano	CHO	+Glucose, pH 2;6;8.	1[8]-14[8]-14[8]-			pH	85
405		Mycelia, cell suspension[4]	37	Mano	CHO	Endogenous; +glucose.	16[8]-23[8]		0.80-0.96	Substrate	86
406	Botrytis allii	Mycelia[4]	25	Mano			11-17.6				87
407	B. cinerea	Mycelia[5]	26	Mano	CHO	1;1.5 da.	7.7-8.5			Age	88
408		Mycelia[5]	26	Mano	CHO	2;3;4;5;6 da.	3.0-2.9-2.0-1.5-1.5		1.5-1.5-1.5-1.5-1.5	Age	88
409		Mycelia[5]	26	Mano	CHO	Endogenous; +pyruvate; acetate; citrate.	2-4-4.5-8.8-2.7-5.4-5.4-10.8			Substrate	88
410		Mycelia[5]	26	Mano	CHO	+Ketoglutarate; succinate; malate; oxalate.	3.1-6.2-3.9-7.8-2.2-4.4-1.9-3.9			Substrate	88
411		Mycelia[5]	26	Mano	CHO	+Glycolate; glucose; fructose.	2.4-4.8-3.4-6.8-3.2-6.4			Substrate	88
412		Mycelia[5]	26	Mano	CHO	+Glucose-1-phosphate; glucose-6-phosphate; fructose-1,6,diphosphate.	1.9-3.9-2.1-4.1-2.1-4.2			Substrate	88
413		Mycelia[5]	26	Mano	CHO	+Gluconate;5-ketogluconate;phosphogluconate.	4.2-8.4-1.9-3.9-3.8-7.6			Substrate	88

414		Mycelia[5]	26	Mano	CHO	+Ribose;xylose;arabinose;ribose-5-phosphate.	2.1-4.3-3.8-7.6-2.8-5.5-3.2-6.4			Substrate	88
415	Brettanomyces anomalus	Cell suspension[4]	30	Mano	CHO			0			89
416	B. claussenii	Cell suspension		Mano	CHO	64-168 hr, grown aerobically.	38-28			Growth	90
417		Cell suspension		Mano	CHO	144 hr, grown anaerobically.	10				90
418	Candida albicans	Cell suspension[5]	30	Mano	End		5			Substrate	91
419		Cell suspension[5]	30	Mano	CHO	+Glucose.	40			Substrate	91
420		Cell suspension[5]		Mano	End				1.0	Starvation	91
421	Cephalothecium roseum	Pellets	23-25	Chem	CHO				1.19		17
422	Cladosporium spp	Pellets	23-25	Chem	CHO	5 strains.			1.10-1.28	Strains	17
423	Clasterosporium spp	Pellets	23-25	Chem	CHO	2 strains.			1.30-1.74	Strains	17
424	Eidamia catenulata	Pellets	23-25	Chem	CHO				1.69		17
425	E. viridescens	Pellets	23-25	Chem	CHO				1.59		17
426	Epicoccum spp	Pellets	23-25	Chem	CHO	2 species.			1.16-1.64		17
427	Epidermophyton	Mycelia		Mano	End		2.0				92
428	floccosum	Mycelia		Mano	End	pH 3.0;5.0;6.0.	3.0;0.8;1.6			pH	93
429	Fumago vagans	Pellets	23-25	Chem	CHO				1.11		17
430	Fusarium avenaceum	Pellets	23-25	Chem	CHO				5.46		94
431	F. coeruleum	Pellets	23-25	Chem	CHO				3.69		94
432	F. dianthi	Pellets	23-25	Chem	CHO				1.85		94
433	F. falcatum	Pellets	23-25	Chem	CHO				4.67		94
434	F. graminearum	Pellets	30	Mano	CHO	45-90 hr.	10-30			Age	95
435		Pellets	30	Mano	CHO	+Glucose; endogenous (whole cells).	15.7-13.6		1.24-0.84	Substrate; method	95
436		Pellets	30	Mano	CHO	+Glucose; endogenous (minced cells).	28.0-25.9		1.11-0.72	Substrate; method	95
437	F. uncinatum	Pellets	23-25	Chem	CHO				4.46		94
438	F. javanicum	Pellets	23-25	Chem	CHO				3.88		94
439	F. lini	Pellets	23-25	Chem	CHO				1.70		94
440	F. martii	Pellets	23-25	Chem	CHO				2.00		94
441	F. metachroum	Pellets	23-25	Chem	CHO				3.32		94
442	F. orthoceras	Pellets	23-25	Chem	CHO				3.30		94
443	F. oxysporum	Pellets	23-25	Chem	CHO				2.78		94
444	F. rhizophilum	Pellets	23-25	Chem	CHO				3.61		94
445	F. salicis	Pellets	23-25	Chem	CHO				6.45		94
446	F. sambucinum	Pellets	23-25	Chem	CHO				4.74		94
447	F. scirpi	Pellets	23-25	Chem	CHO				3.17		94
448	F. solani var. minus	Pellets	23-25	Chem	CHO				1.45		94
449	F. sporotrichoides	Pellets	23-25	Chem	CHO				1.90		94
450	F. trichothecioides	Pellets	23-25	Chem	CHO				5.24		94
451		Mycelia[9]	30	Mano	End	1-4 hr (1 da-old mycelia).	40-13	31-11	0.78-0.84	Substrate; age	96
452		Mycelia[9]	30	Mano	CHO	+Glucose, 1-4 hr (1 da-old mycelia).	34-39	64-56	1.85-1.55	Substrate; age	96
453		Mycelia[9]	30	Mano	End	1-4 hr (3 da-old mycelia).	14-13	14-12	1.01-0.92	Substrate; age	96
454		Mycelia[9]	30	Mano	CHO	+Glucose, 1-4 hr (3 da-old mycelia).	14-13	19-26	1.36-1.97	Substrate; age	96

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Values for rates of gaseous exchange are given in µl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate µl/mg/hr		R.Q. CO_2/O_2	Experimental Variable	Reference
							Q_{O_2}	Q_{CO_2}			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Fungi Imperfecti (continued)					
455	Fusarium trichothecioides (concluded)	Mycelia[9]	30	Mano	End	Grown on glucose.			0.88-0.95	Substrate	96
456		Mycelia[9]	30	Mano	CHO	Grown on glucose.			1.75-1.84	Substrate	96
457		Mycelia[9]	30	Mano	CHO	Endogenous; +galactose.			1.58-2.33	Substrate	96
458		Mycelia[9]	30	Mano	CHO	Endogenous; +glucose and galactose.			1.20-2.30	Substrate	96
459		Mycelia[9]	30	Mano	CHO	Endogenous; +xylose.			1.00-0.98	Substrate	96
460		Mycelia[9]	30	Mano	CHO	Endogenous; +arabinose.			0.87-0.89	Substrate	96
461		Mycelia[9]	30	Mano	CHO	Endogenous; +glycerol.			0.92-0.64	Substrate	96
462		Mycelia[9]	30	Mano	CHO	Endogenous; +lactate.			0.91-0.68	Substrate	96
463		Mycelia[9]	30	Mano	CHO	+Mannose, grown on glucose.			1.67-1.71	Substrate	96
464		Mycelia[9]	30	Mano	CHO	+Galactose, grown on glucose.			0.90-0.95	Substrate	96
465		Mycelia[9]	30	Mano	CHO	+Glucose and mannose, grown on glucose.			1.70	Substrate	96
466		Mycelia[9]	30	Mano	CHO	+Glucose and galactose, grown on glucose.			1.75-1.80	Substrate	96
467		Mycelia[9]	30	Mano	CHO	+Fructose, grown on glucose.			1.33-1.37	Substrate	96
468		Mycelia[9]	30	Mano	CHO	+Xylose, grown on glucose.			0.87-0.95	Substrate	96
469		Mycelia[9]	30	Mano	CHO	+Arabinose, grown on glucose.			0.89-0.93	Substrate	96
470		Mycelia[9]	30	Mano	CHO	+Sucrose, grown on glucose.			1.09-1.14	Substrate	96
471		Mycelia[9]	30	Mano	CHO	+Maltose, grown on glucose.			0.89-0.93	Substrate	96
472		Mycelia[9]	30	Mano	CHO	+Lactose, grown on glucose.			0.83-0.89	Substrate	96
473		Mycelia[9]	30	Mano	CHO	+Mannitol, grown on glucose.			0.89-0.90	Substrate	96
474		Mycelia[9]	30	Mano	CHO	+Glycerol, grown on glucose.			0.59-0.61	Substrate	96
475		Mycelia[9]	30	Mano	CHO	+α-Glycerol phosphate, grown on glucose.			0.51-0.61	Substrate	96
476		Mycelia[9]	30	Mano	CHO	+Hexose diphosphate, grown on glucose.			0.95	Substrate	96
477		Mycelia[9]	30	Mano	CHO	+Pyruvate, grown on glucose.			1.35-1.44	Substrate	96
478		Mycelia[9]	30	Mano	CHO	+Pyruvate and glucose, grown on glucose.			2.08-2.17	Substrate	96

479		Mycelia[9]	30	Mano	CHO	+Succinate, grown on glucose.			0.86-0.96	Substrate	96
480		Mycelia[9]	30	Mano	CHO	+Lactate, grown on glucose.			0.78-0.84	Substrate	96
481		Mycelia[9]	30	Mano	CHO	+Acetate, grown on glucose.			0.86-0.96	Substrate	96
482	F. tubercularioides	Pellets	23-25	Chem	CHO				5.10		94
483	F. vasinfectum	Pellets	23-25	Chem	CHO				2.76		94
484	F. viride	Pellets	23-25	Chem	CHO				1.45		94
485	Fusarium sp H	Mycelia		Mano	CHO	Endogenous; +glucose.	7.3-6.1	6.7-10.2	0.95-1.75	Substrate	97
486		Mycelia		Mano	CHO	+Glucose.		3.4		Substrate	97
487	Gliocladium roseum	Pellets	23-25	Chem	CHO				1.44		94
488	Helminthosporium geniculatum	Pellets	23-25	Chem	CHO				1.56		17
489	H. gramineum	Pellets	23-25	Chem	CHO				1.31		17
490	H. inaequalis	Pellets	23-25	Chem	CHO				1.16		17
491	H. interseminatum	Pellets	23-25	Chem	CHO				1.07		17
492	H. teres	Pellets	23-25	Chem	CHO				1.13		17
493	Heterosporium gracile	Pellets	23-25	Chem	CHO				1.09		17
494	H. variabile	Pellets	23-25	Chem	CHO				1.17		17
495	Memnoniella echinata	Conidia	30	Mano	CHO	+Raffinose, pH 4;6;8.	3.9-3.7-3.8			pH	68
496		Conidia	30	Mano	CHO	+Melezitose, pH 4;6;8.	1.3-1.8-1.6			pH	68
497		Conidia	30	Mano	CHO	+Sucrose, pH 4;6;8.	3.5-4.0-3.6			pH	68
498		Conidia	30	Mano	CHO	+Furanose, pH 4;6;8.	1.9-2.4-2.0			pH	68
499		Conidia	30	Mano	CHO	+Maltose, pH 4;6;8.	2.2-3.6-3.2			pH	68
500		Conidia	30	Mano	CHO	+Cellobiose, pH 4;6;8.	1.3-3.5-1.8			pH	68
501		Conidia	30	Mano	CHO	+Trehalose, pH 4;6;8.	1.7-2.8-2.9			pH	68
502		Conidia	30	Mano	CHO	+Lactose, pH 4;6;8.	0.7-1.3-1.2			pH	68
503		Conidia	30	Mano	CHO	+Melibiose, pH 4;6;8.	2.5-4.0-2.8			pH	68
504		Conidia	30	Mano	CHO	+Glucose, pH 4;6;8.	2.6-3.1-2.7			pH	68
505		Conidia	30	Mano	CHO	+Fructose, pH 4;6;8.	2.4-3.1-2.5			pH	68
506		Conidia	30	Mano	CHO	+Galactose, pH 4;6;8.	2.6-3.9-3.1			pH	68
507		Conidia	30	Mano	CHO	+Mannose, pH 4;6;8.	3.0-4.4-2.1			pH	68
508		Conidia	30	Mano	CHO	+Sorbose, pH 4;6;8.	1.6-2.3-1.9			pH	68
509		Conidia	30	Mano	CHO	Endogenous, pH 4;6;8.	1.0-1.5-1.3			pH	68
510		Conidia	30	Mano	CHO	Endogenous.	0.8			Substrate	68
511		Conidia	30	Mano	CHO	+Glucose.	0.8-10.4			Substrate	68
512		Conidia	30	Mano	CHO	+Glucose and biotin.	0.8-10.4			Substrate; accessory growth factors	68
513		Conidia	30	Mano	CHO	+Glucose and yeast extract.	0.8-31			Substrate; accessory growth factors	68
514	Microsporum canis	Pellets	37.5	Mano		0-3 da starvation.			1.0-0.87	Starvation	98
515	Mycoderma vini	Cell suspension[4]	29	Mano	Org	+Ethanol.			0.67	Substrate	62
516		Cell suspension[4]	10-37	Mano			25-20			Temperature	62
517		Cell suspension[4]	29	Mano	Org	+Acetaldehyde.			0.77	Substrate	62
518		Cell suspension[4]	29	Mano	Org	+Acetate.			1.02	Substrate	62
519	Myrothecium verrucaria	Conidia	30	Mano	CHO	+Sucrose.	100[7]-150[7]			Substrate	99
520		Conidia	30	Mano	CHO	+Sucrose, 1-3 hr.		3.8	1.16-1.25	Substrate	100

/1/ Mano = manometric; Chem = chemical; Volu = volumetric; Cond = conductometric; Pola = polarographic. /2/ End = endogenous; CHO = carbohydrates; Com = complex substrates; Nat = natural; Org = organic compounds. /4/ Washed. /7/ μl/10^8 cells/hr. /9/ Homogenized.

Values for rates of gaseous exchange are given in µl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate µl/mg/hr Q_{O_2}	Respiration Rate µl/mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Fungi Imperfecti (continued)					
521	Myrothecium verrucaria (continued)	Conidia	30	Mano	CHO	+Fructose, 1-3 hr.		<u>2.3</u>	1.25-1.28	Substrate	100
522		Conidia	30	Mano	CHO	+Glucose, 1-3 hr.		<u>5.2</u>	1.15-1.24	Substrate	100
523		Conidia	30	Mano	End	1-3 hr.		<u>1.9</u>	0.91-0.79	Substrate	100
524		Conidia	30	Mano	End	-;+10^{-3}M azide.	3.3-28.4			Inhibitors	100
525		Conidia	30	Mano	CHO	+Raffinose, pH 4;6;8.	8.3-11.3-16.0			pH	68
526		Conidia	30	Mano	CHO	+Melezitose, pH 4;6;8.	2.8-9.9-11.3			pH	68
527		Conidia	30	Mano	CHO	+Sucrose, pH 4;6;8.	19.0-25.0-30.1			pH	68
528		Conidia	30	Mano	CHO	+Furanose, pH 4;6;8.	11.7-15.7-19.2			pH	68
529		Conidia	30	Mano	CHO	+Maltose, pH 4;6:8.	3.9-12.7-14.5			pH	68
530		Conidia	30	Mano	CHO	+Cellobiose, pH 4;6;8.	3.4-4.2-7.3			pH	68
531		Conidia	30	Mano	CHO	+Trehalose, pH 4;6;8.	6.1-6.3-7.3			pH	68
532		Conidia	30	Mano	CHO	+Lactose, pH 4;6;8.	2.6-2.3-5.8			pH	68
533		Conidia	30	Mano	CHO	+Melibiose, pH 4;6;8.	2.9-4.3-8.8			pH	68
534		Conidia	30	Mano	CHO	+Glucose, pH 4;6;8.	11.4-13.5-23.6			pH	68
535		Conidia	30	Mano	CHO	+Fructose, pH 4;6;8.	9.3-12.9-15.0			pH	68
536		Conidia	30	Mano	CHO	+Galactose, pH 4;6;8.	8.2-9.5-15.6			pH	68
537		Conidia	30	Mano	CHO	+Mannose, pH 4;6;8.	16.2-23.9-29.9			pH	68
538		Conidia	30	Mano	CHO	+Sorbose, pH 4;6;8.	4.3-10.8-11.4			pH	68
539		Conidia	30	Mano	CHO	+Xylose, pH 6.	10.0			pH	68
540		Conidia	30	Mano	End	Endogenous, pH 4;6;8.	2.9-2.6-5.6			pH	68
541		Conidia	30	Mano	CHO	0;1;3 hr, germinating spores.	2-65-75			Age	100
542		Conidia	30	Mano	CHO	+DL-Alanine.	8.8			Substrate	100
543		Conidia	30	Mano	CHO	+L(+) Arginine.	2.5			Substrate	100
544		Conidia	30	Mano	CHO	+DL-Aspartic acid.	3.3			Substrate	100
545		Conidia	30	Mano	CHO	+L(+) Glutamic acid.	2.0-5.6			Substrate	100
546		Conidia	30	Mano	CHO	+Glycine.	6.7			Substrate	100
547		Conidia	30	Mano	CHO	+L-Histidine.	2.5			Substrate	100
548		Conidia	30	Mano	CHO	+L-Leucine.	7.0			Substrate	100
549		Conidia	30	Mano	CHO	+L-Proline.	6.3-11.0			Substrate	100
550		Conidia	30	Mano	CHO	+Casein hydrolysate.	34.0			Substrate	100
551		Conidia	30	Mano	CHO	+Asparagine.	4.5			Substrate	100
552		Conidia	30	Mano	CHO	+Citrate.	2.1			Substrate	100
553		Conidia	30	Mano	CHO	+Ethanol.	9.5			Substrate	100
554		Conidia	30	Mano	CHO	+Ethylene glycol.	3.0			Substrate	100
555		Conidia	30	Mano	CHO	+Fumarate.	8.2			Substrate	100
556		Conidia	30	Mano	CHO	+Glycerol.	28-35			Substrate	100

557		Conidia	30	Mano	CHO	+1-Malate.	5.3			Substrate	100
558		Conidia	30	Mano	CHO	+Mannitol.	4.7			Substrate	100
559		Conidia	30	Mano	CHO	+Pyruvate.	10.0			Substrate	100
560		Conidia	30	Mano	CHO	+Succinate.	7.5			Substrate	100
561		Conidia	30	Mano	CHO	+Tartrate.	6.5			Substrate	100
562		Conidia	30	Mano	CHO	+Urea.	3.5			Substrate	100
563		Pellets[4,5]	30	Mano	End	Raffinose grown.	6-8			Substrate	101
564		Pellets[4,5]	30	Mano	CHO	Raffinose grown, + maltose; glucose; galactose; fructose.	58-58-65-61			Substrate	101
565		Pellets[4,5]	30	Mano	CHO	Raffinose grown, + sucrose; raffinose; melezitose; cellobiose; melibiose.	48-39-40-42-46			Substrate	101
566		Pellets[4,5]	30	Mano	CHO	Raffinose grown, + lactose.	22			Substrate	101
567		Pellets[4,5]	30	Mano	End	Melezitose grown, starved.	4-10			Substrate	101
568		Pellets[4,5]	30	Mano	CHO	Melezitose grown. + maltose; melibiose; glucose; galactose; fructose.	59-45-61-64-64			Substrate	101
569		Pellets[4,5]	30	Mano	CHO	Melezitose grown, + sucrose; raffinose; melezitose; lactose; cellobiose.	31-21-22-15-32			Substrate	101
570		Pellets[4,5]	30	Mano	End	Sucrose grown.	14-18			Substrate	101
571		Pellets[4,5]	30	Mano	CHO	Sucrose grown, + sucrose; maltose; cellobiose; fructose.	42-47-47-64			Substrate	101
572		Pellets[4,5]	30	Mano	CHO	Sucrose grown, + lactose; melibiose; glucose; galactose.	20-25-34-36			Substrate	101
573		Pellets[4,5]	30	Mano	CHO	Maltose grown, starved.	12-13			Substrate	101
574		Pellets[4,5]	30	Mano	CHO	Maltose grown, + maltose; galactose.	60-67			Substrate	101
575		Pellets[4,5]	30	Mano	CHO	Maltose grown, + fructose; raffinose; sucrose; cellobiose; glucose.	56-50-47-47-54			Substrate	101
576		Pellets[4,5]	30	Mano	CHO	Maltose grown, + lactose; melezitose; melibiose.	34			Substrate	101
577		Pellets[4,5]	30	Mano	End	Cellobiose grown.	8-16			Substrate	101
578		Pellets[4,5]	30	Mano	CHO	Cellobiose grown, + fructose; glucose; galactose; maltose.	91-67-58-50			Substrate	101
579		Pellets[4,5]	30	Mano	CHO	Cellobiose grown, + sucrose; raffinose; cellobiose; lactose; melezitose.	34-35-42-31-30			Substrate	101

/1/ Mano = manometric; Chem = chemical; Volu = volumetric; Cond = conductometric; Pola = polarographic. /2/ End = endogenous; CHO = carbohydrates; Com = complex substrates; Nat = natural; Org = organic compounds. /4/ Washed. /5/ Starved.

Values for rates of gaseous exchange are given in µl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rates µl/mg/hr Q_{O_2}	Respiration Rates µl/mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Fungi Imperfecti (continued)					
580	Myrothecium verrucaria (concluded)	Pellets[4,5]	30	Mano	CHO	Cellobiose grown, + melibiose.	19			Substrate	101
581		Pellets[4,5]	30	Mano	End	Lactose grown.	21-23			Substrate	101
582		Pellets[4,5]	30	Mano	CHO	Lactose grown, + maltose; galactose; cellobiose; melibiose.	35-36-30-30			Substrate	101
583		Pellets[4,5]	30	Mano	CHO	Lactose grown, + lactose; sucrose; glucose; fructose.	26-28-25-27			Substrate	101
584		Pellets[4,5]	30	Mano	End	Melibiose grown, starved.	6			Substrate	101
585		Pellets[4,5]	30	Mano	CHO	Melibiose grown, + cellobiose.	51			Substrate	101
586		Pellets[4,5]	30	Mano	CHO	Melibiose grown, + maltose, glucose; galactose.	31-28-26			Substrate	101
587		Pellets[4,5]	30	Mano	CHO	Melibiose grown, + lactose; melibiose.	9			Substrate	101
588		Pellets[4,5]	30	Mano	End	Glucose grown.	8			Substrate	101
589		Pellets[4,5]	30	Mano	CHO	Glucose grown, + sucrose; cellobiose; glucose; galactose.	21-18-20-22			Substrate	101
590		Pellets[4,5]	30	Mano	CHO	Glucose grown, + lactose; melibiose.	9			Substrate	101
591		Pellets[4,5]	30	Mano	CHO	Galactose grown, starved.	4			Substrate	101
592		Pellets[4,5]	30	Mano	CHO	Galactose grown, + sucrose; maltose; cellobiose; glucose; galactose; fructose.	19-15-17-17 16-14			Substrate	101
593		Pellets[4,5]	30	Mano	CHO	Galactose grown, + lactose; melibiose.	7-9			Substrate	101
594		Pellets[4,5]	30	Mano	End	Fructose grown.	12-17			Substrate	101
595		Pellets[4,5]	30	Mano	CHO	Fructose grown, + sucrose; maltose, cellobiose.	59-55-57			Substrate	101
596		Pellets[4,5]	30	Mano	CHO	Fructose grown, + glucose; galactose; fructose.	43-46-46			Substrate	101
597		Pellets[4,5]	30	Mano	CHO	Fructose grown, + lactose; melibiose.	15-20			Substrate	101

598		Pellets[4,5]	30	Mano	End	Malt extract and sucrose grown.	4-6			Substrate	101
599		Pellets[4,5]	30	Mano	CHO	Malt extract and sucrose grown, + sucrose; maltose; fructose; cellobiose; galactose; glucose; melibiose.	35-28-26-33-30-33-35			Substrate	101
600		Pellets[4,5]	30	Mano	CHO	Malt extract and sucrose grown, + lactose.	15			Substrate	101
601		Mycelia[4,9]	30	Mano	Com	4;24;100 hr.	45-108-22			Age	102
602		Mycelia[4,9]	30	Mano	CHO	0-1 min grinding in Potter mill.	38-5			Method	102
603		Mycelia[4,9]	30	Mano	End	0;20;60 hr starvation.	58-15-2			Starvation	102
604		Mycelia[4,9]	30	Mano	CHO			0	1.0		102
605	Oidium lactis	Mycelia	15	Chem	CHO				0.70	Temperature	8
606		Mycelia	35	Chem	CHO				0.72	Temperature	8
607	Paecilomyces varioti	Pellets	23-25	Chem	CHO				1.37		94
608	Penicillium avellaneum	Pellets	23-25	Chem	CHO				1.12		94
609	P. baculatum	Pellets	23-25	Chem	CHO				1.12		94
610	P. biourgeianum	Pellets	23-25	Chem	CHO				1.16		94
611	P. camemberti	Pellets	23-25	Chem	CHO				1.08		94
612	P. caseicolum	Pellets	23-25	Chem	CHO	2 strains.			1.12	Strains	94
613	P. chrysogenum	Pellets	23-25	Chem	CHO	3 strains.			1.10-1.27	Strains	94
614		Pellets	23-24	Mano	Com	2;3;4 da.	17-29-9			Age	103
615		Pellets	23-24	Mano	Com	2;3;4 da.	1.3[8]-3.4[8]-1.0[8]			Age	103
616		Pellets	23-24	Mano	Com	At 3 da.	256[8]-342[8]				104
617		Pellets	25-28	Volu	Com	250;575 rpm stirring.	4.5-15.6			Method	105
618		Pellets[5]	27	Mano	CHO		3.1-9.0				106
619	P. citrinum	Pellets	23-25	Chem	CHO				1.23		94
620	P. commune	Pellets	23-25	Chem	CHO				1.41		94
621	P. corymbiferum	Pellets	23-25	Chem	CHO	2 strains.			1.62-1.78	Strains	94
622	P. crustosum	Pellets	23-25	Chem	CHO				1.64		94
623	P. daleae	Pellets	23-25	Chem	CHO				1.93		94
624	P. digitatum	Pellets	23-25	Chem	CHO	4 strains.			1.39-1.63		94
625	P. duclauxi	Pellets	23-25	Chem	CHO	2 strains.			1.79-2.82	Strains	94
626	P. expansum	Pellets	23-25	Chem	CHO	2 strains.			1.22-1.55	Strains	94
627	P. fusco-glaucum	Pellets	23-24	Chem	CHO				1.68		94
628	P. glabrum	Pellets	23-25	Chem	CHO	6 strains.			1.14-1.30	Strains	94
629	P. gladioli	Pellets	23-24	Chem	CHO				1.30		94
630	P. glaucum	Growing culture		Chem	CHO	+Glucose.			1.0	Substrate	107
631		Growing culture		Chem	Org	+Quinic acid.			1.22	Substrate	107
632		Growing culture		Chem	Org	+Tartaric acid.			2.90	Substrate	107
633		Growing culture		Chem	Org	+Acetylamin.			0.67	Substrate	107
634		Mycelia	15	Chem	CHO			17-4		Substrate	77
635		Mycelia	15	Chem	Com			14-14		Substrate	77
636		Mycelia	25	Chem	Com			74-2		Substrate	77
637		Mycelia	25	Chem	End			20-9.4			77
638		Mycelia	25	Chem	Com	Endogenous; exogenous.		6-28			77

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Values for rates of gaseous exchange are given in µl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate µl/mg/hr Q_{O_2}	Respiration Rate µl/mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Fungi Imperfecti (continued)					
639	Penicillium glaucum (concluded)	Mycelia	25	Chem	Org	+Tartrate.		26-$\underline{7}$			77
640	P. godlewskii	Pellets	23-25	Chem	CHO				1.14		94
641	P. herquei	Pellets	23-25	Chem	CHO				1.17		94
642	P. italicum	Pellets	23-25	Chem	CHO	2 strains.			1.25-1.32	Strains	94
643	P. kiliense	Pellets	23-25	Chem	CHO				1.05		94
644	P. lanoso-coeruleum	Pellets	23-25	Chem	CHO				1.21		94
645	P. lanoso-viride	Pellets	23-25	Chem	CHO				1.69		94
646	P. lanosum	Pellets	23-25	Chem	CHO				1.14		94
647	P. lilacinum	Pellets	23-25	Chem	CHO	2 strains.			1.40-1.57	Strains	94
648	P. luteum	Pellets	23-25	Chem	CHO				1.04		94
649	P. meleagrinum	Pellets	23-25	Chem	CHO				1.24		94
650	P. notatum	Pellets	23-25	Chem	CHO				1.04		94
651		Mycelia	24	Chem	Com	4;8;11 da.		46-198-152		Age	108
652		Pellets	23-24	Mano	Com	3-5 da.	1.08[8]-1.32[8]			Age	104
653		Mycelia[5]	20-24	Mano	End	0-1 da.	6.5-1.7			Age	109
654		Mycelia[5]	20-24	Mano	CHO	2;4;7 da.	6;16;2			Age	109
655	P. ochraceum	Pellets	23-24	Chem	CHO				1.65		94
656	P. pfefferianum	Pellets	23-25	Chem	CHO	7 strains.			1.05-1.21	Strains	94
657	P. pinophilum	Pellets	23-25	Chem	CHO				1.10		94
658	P. psittacinum	Pellets	23-25	Chem	CHO				1.40		94
659	P. puberulum	Pellets	23-25	Chem	CHO				1.57		94
660	P. purpurogenum	Pellets	23-25	Chem	CHO				1.77		94
661	P. rugulosum	Pellets	23-25	Chem	CHO				1.11		94
662	P. schneggii	Pellets	23-25	Chem	CHO				1.45		94
663	P. spiculisporum	Pellets	23-25	Chem	CHO				4.03		94
664	P. steckii	Pellets	23-25	Chem	CHO				1.15		94
665	P. tardum	Pellets	23-25	Chem	CHO	2 strains.			1.05-1.56	Strains	94
666	P. terrestre	Pellets	23-25	Chem	CHO	8 strains.			1.19-2.26	Strains	94
667	P. verrucosum	Pellets	23-25	Chem	CHO				2.00		94
668	P. viridicatum	Pellets	23-25	Chem	CHO				1.06-1.26		94
669	Rhacodium cellare	Pellets	23-25	Chem	CHO				1.03		17
670	Scopulariopsis brevicaulis	Pellets	23-25	Chem	CHO	3 strains.			1.20-1.33	Strains	94
671	Sporotrichum bombycinum	Pellets	23-25	Chem	CHO				1.28		17
672	S. carneolum	Pellets	23-25	Chem	CHO				1.16		17
673	Stysanus sp	Pellets	23-25	Chem	CHO				1.21		17
674	Torula sp	Cell suspension[4]	30	Mano	CHO	±Glutathione; ±cysteine.	28	9		Accessory growth factors	42

675	Torulopsis dattila	Cell suspension[4]	30	Mano	CHO	Endogenous.		0			89
676	T. utilis	Cell suspension	30	Mano	End	No N added.	3.4[3]		0.93	Inorganic nutrition; substrate	110
677		Cell suspension	30	Mano	End	+Ethylamine HCl.	3.5[3]		0.83	Inorganic nutrition; substrate	110
678		Cell suspension	30	Mano	End	+Glycine.	3.7[3]		0.86	Inorganic nutrition; substrate	110
679		Cell suspension	30	Mano	End	+Asparagine.	3.8[3]		0.96	Inorganic nutrition; substrate	110
680		Cell suspension	30	Mano	End	+Urea.	3.5[3]		1.15	Inorganic nutrition; substrate	110
681		Cell suspension	30	Mano	End	+α-Alanine.	5.2[3]		0.89	Inorganic nutrition; substrate	110
682		Cell suspension	30	Mano	End	+β-Alanine.	4.2[3]		1.16	Inorganic nutrition; substrate	110
683		Cell suspension	30	Mano	End	+$(NH_4)_2SO_4$.	3.4[3]		0.95	Inorganic nutrition; substrate	110
684		Cell suspension	30	Mano	End	+Diethylamine HCl.	3.7[3]		0.93	Inorganic nutrition; substrate	110
685		Cell suspension	30	Mano	End	+Dimethylurea.	3.3[3]		0.94	Inorganic nutrition; substrate	110
686		Cell suspension	30	Mano	End	+Guanidine SO_4.	3.6[3]		1.20	Inorganic nutrition; substrate	110
687		Cell suspension	30	Mano	End	+Methylamine HCl.	3.5[3]		0.92	Inorganic nutrition; substrate	110
688		Cell suspension	30	Mano	End	+Propylamine HCl.	3.9[3]			Inorganic nutrition; substrate	110
689		Cell suspension	30	Mano	End	N starved.	3.9[3]	3.8[3]	0.97	Inorganic nutrition; substrate	110
690		Cell suspension	30	Mano	End	$(NH_4)_2SO_4$, N starved.	5.8[3]	5.2[3]	0.90	Inorganic nutrition; substrate	110
691		Cell suspension	30	Mano	End	+Ethylamine HCl, N starved.	8.4[3]	6.8[3]	0.80	Inorganic nutrition; substrate	110
692		Cell suspension	30	Mano	End	+Glycine, N starved.	8.1[3]	8.6[3]	1.06	Inorganic nutrition; substrate	110
693		Cell suspension	30	Mano	End	+Asparagine, N starved.	8.6[3]	9.9[3]	1.15	Inorganic nutrition; substrate	110
694		Cell suspension	30	Mano	End	+Urea, N starved.	5.7[3]	6.3[3]	1.11	Inorganic nutrition; substrate	110
695		Cell suspension	30	Mano	End	+α-Alanine, N starved.	15.0[3]	14.2[3]	0.95	Inorganic nutrition; substrate	110
696		Cell suspension	30	Mano	End	+β-Alanine, N starved.	8.8[3]	8.8[3]	1.00	Inorganic nutrition; substrate	110
697		Cell suspension	30	Mano	End	+Diethylamine HCl, N starved.	5.7[3]	5.2[3]	0.91	Inorganic nutrition; substrate	110
698		Cell suspension	30	Mano	End	+Dimethylurea, N starved.	4.5[3]	4.4[3]	0.98	Inorganic nutrition; substrate	110
699		Cell suspension	30	Mano	End	+Guanidine SO_4, N starved.	6.0[3]	6.4[3]	1.07	Inorganic nutrition; substrate	110

/1/ Mano = manometric; Chem = chemical; Volu = volumetric; Cond = conductometric; Pola = polarographic. /2/ End = endogenous; CHO = carbohydrates; Com = complex substrates; Nat = natural; Org = organic compounds. /3/ µl/mg wet wt/hr. /4/ Washed. /5/ Starved. /8/ µl/10 µl tissue volume/hr.

Values for rates of gaseous exchange are given in µl/mg dry weight/hour, unless otherwise specified. Species names in parentheses are former nomenclature. Column H: Numbers underscored = values for anaerobic CO_2 production; numbers not underscored = values for aerobic CO_2 production.

	Species	Material	Temp °C	Method[1]	Substrate[2]	Specifications	Respiration Rate µl/mg/hr Q_{O_2}	Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
						Fungi Imperfecti (concluded)					
700	Torulopsis utilis (concluded)	Cell suspension	30	Mano	End	+Methylamine HCl, N starved.	7.8[3]	7.1[3]	0.91	Inorganic nutrition; substrate	110
701		Cell suspension	30	Mano	End	+Propylamine HCl, N starved.	10.0[3]	7.7[3]	0.77	Inorganic nutrition; substrate	110
702		Cell suspension	30	Mano	CHO	No N added, N sufficient; N starved.			1.13-1.06	Inorganic nutrition; substrate	110
703		Cell suspension	30	Mano	CHO	+$(NH_4)_2SO_4$, N sufficient; N starved.			1.08-1.06	Inorganic nutrition; substrate	110
704		Cell suspension	30	Mano	CHO	+Ethylamine HCl, N sufficient; N starved.			0.86-0.82	Inorganic nutrition; substrate	110
705		Cell suspension	30	Mano	CHO	+Asparagine, N sufficient; N starved.			1.24-1.18	Inorganic nutrition; substrate	110
706		Cell suspension	30	Mano	CHO	+Urea, N sufficient; N starved.			1.16-1.21	Inorganic nutrition; substrate	110
707		Cell suspension	30	Mano	CHO	+α-Alanine, N sufficient; N starved.			1.08-1.08	Inorganic nutrition; substrate	110
708		Cell suspension	30	Mano	CHO	+Guanidine SO_4; N sufficient; N starved.			1.21-1.14	Inorganic nutrition; substrate	110
709	Trichoderma lignorum	Pellets	23-25	Chem	CHO				1.20		17
710	Trichoderma sp	Pellets	23-25	Chem	CHO				1.40		17
711	Trichophyton gypseum	Mycelia		Mano	End				1.7		92
712		Mycelia		Mano	End	pH 4.6;7.0;8.0.	1.06-1.73-2.69			pH	93
713	T. rubrum	Mycelia		Mano	End	pH 4.6;8.0.	0.80-0.72			pH	93

/1/ Mano = manometric; Chem = chemical; Volu = volumetric; Cond = conductometric; Pola = polarographic. /2/ End = endogenous; CHO = carbohydrates; Com = complex substrates; Nat = natural; Org = organic compounds. /3/ µl/mg wet wt/hr.

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161. RESPIRATION RATES: LIVERWORTS AND MOSSES

Values for rates of gaseous exchange are µl/100 mg dry weight/hour, unless otherwise specified. Material consists of entire plant, unless otherwise specified.

	Species	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Liverworts							
1	Chiloscyphus fragilis	25	Mano	60-100			Substrates; inhibitors	1
2	Frullania tamarisci				32-47		Light	2
3	Marchantia polymorpha	20	Chem		0.6[2]			3
4	Riccia fluitans	25	Mano	250-300			Substrates; inhibitors	1
	Mosses							
5	Fissidens taxifolius				30			2
6	Fontinalis antipyretica				105			2
7		25	Mano	70-140			Substrates; inhibitors	1
8	Hylocomium parietinum	30	Chem		92			4
9		20	Chem		46			4
10		0			15			4
11	H. proliferum	30	Chem		92			4
12		20	Chem		46			4
13		0	Chem		15			4
14	H. squarrosum	30	Chem		100			4
15		20	Chem		61			4
16		5	Chem		15			4
17	Hypnum cupressiforme	18.5	Chem	2-30			Moisture	5
18					74			2
19	H. fluitans	18	Chem		0.83[3]			6
20	H. triquetrum	20			0.8-30.0		Moisture	7
21			Mano	0.5-40.0			Moisture	8
22	Mnium undulatum				7.5-97.0		Moisture	2
23	Orthotrichum affine	55	Mano		12	0.70		9
24	Polytrichum juniperinum[4]	18			1.2-0.7[3]	1.00-0.65	Growth, development, maturation	10
25	Sphagnum cuspidatum				73-137	1.00-0.94		2
26	S. girgensohnii	30	Chem		130			4
27		20	Chem		71			4
28		5	Chem		20			4

/1/ Mano = manometric, Chem = chemical. /2/ µl/sq cm/hour. /3/ µl/100 mg wet weight/hour. /4/ Shoots or tops.

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162. RESPIRATION RATES: HORSETAILS AND FERNS

Values for rates of gaseous exchange are µl/100 mg wet weight/hour.

	Species	Material	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr		R.Q. CO_2/O_2	Reference
					Q_{O_2}	Q_{CO_2}		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Horsetails							
1	Equisetum maximum	Shoot or top	20	Mano		6	0.78	1
2		Fruiting shoot or top	20	Mano		100	0.83	1
3		Stem	RT	Mano		9.6	0.80	2
4		Branchlet	RT	Mano		19	0.69	2
	Ferns							
5	Asplenium adiantum nigrum	Frond with sori	20	Mano		17	1.01	1
6		Frond	20	Mano		13	0.86	1
7		Blade	RT	Mano		13.4	0.80	2
8		Petiole	RT	Mano		8.3	0.80	2
9	Dryopteris austriaca	Frond	48	Chem		122		3
10		Frond	30	Chem		36		3
11		Frond	10	Chem		25		3
12	Eupteris aquilina	Frond	48	Chem		168		3
13		Frond	30	Chem		46		3
14		Frond	10	Chem		15		3
15		Frond	15.5	Chem		265-66[3]		3
16	Polypodium vulgare	Frond with sori	20	Mano		19	1.06	1
17		Frond	20	Mano		10	0.92	1
18		Frond	16	Chem		250-86[3]		3
19	Pteris aquilina	Frond with sori	22	Mano		35	1.01	1
20		Frond	22	Mano		19	0.84	1
21	Scolopendrium scolopendrium	Frond	25	Mano	23-130-40[3]			4
22		Frond	30	Mano	31			4
23		Frond	22	Mano	17.5			4
24		Frond	13	Mano	9.9			4
25		Frond	3	Mano	2.2			4

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical. /3/ Effect of growth, development, maturation.

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163. RESPIRATION RATES: HIGHER PLANTS, SEEDS

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value. For data on certain cereal "seeds" during development and maturation, see HIGHER PLANTS: FRUITS, beginning on Page 377.

	Species	Condition or Part	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr		R.Q. CO_2/O_2	Experimental Variable	Reference
					Q_{O_2}	Q_{CO_2}			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Acacia melanoxylon (blackwood acacia)	Resting		Mano		0.01[2]			1
2	Acer saccharum (sugar maple)	Resting				14			2
3	Aleurites sp (tung)	Embryo, endosperm					1.0-1.7	Growth, development, maturation	3
4	Amaranthus retroflexus (amaranth)	Moist	25	Mano	6.7		0.86		4
5	Amygdalus communis (almond)	Germinating		Mano			0.7-0.86	Growth, development, maturation	5
6	Avena sativa (oat)	Seedling					0.89-1.49	Oxygen	6
7		Resting	37.8	Chem		0.002-0.17[2]		Moisture	7
8	A. sativa (oat, Fulghum)	Embryo, segment	26	Mano	400-140[2]			Oxygen	8
9	A. sativa (oat, Gopher)	Resting	38			0.02-0.78[2]		Moisture	9
10	A. sativa (oat, Sieges Hafer)	Coleoptile		Mano			0.82-1.29	pH; carbohydrates; hormones	10
11		Coleoptile, segment	30	Mano	47-39			Substrate	11
12	A. sativa (oat, States Pride)	Coleoptile	25	Mano	360[2]			Organic acids; metabolic poisons; hormones	12
13	Brassica alba (wild mustard)	Resting	26	Chem		33-15	0.87-0.45	Carbon dioxide	13
14	B. napus (rape)	Seedling	19	Chem		25			6
15	Cannabis sativa (hemp)	Resting	18	Mano	11		0.82		14
16		Germinating	18	Mano	105		0.66		14
17	Chenopodium album (goosefoot)	Moist	25	Mano	9.6		0.93		4
18	Citrullus vulgaris (watermelon)	Resting	28	Mano			0.90		15
19	Cocos nucifera (coconut)	Embryo	30	Mano	400-50[2]			Development	16
20		Hypocotyl	30	Mano	64[2]				16
21		Endosperm	30	Mano	0[2]				16
22	Crataegus sp (hawthorn)	Moist	25	Mano	4.4		0.77		4
23	Cucurbita melanospermum (gourd)	Seedling					0.73-2.2	Oxygen	6
24	C. pepo (pumpkin)	Germinating				45			17
25	C. pepo (Sutton's long white vegetable marrow)	Germinating	25	Chem			0.95-0.63		18
26	C. pepo (Sutton's long white vegetable marrow)	Germinating	25	Chem		10-117	0.94-0.62		19
27	Cytisus laburnum (broom)	Resting	28	Mano			1.16		15
28		Resting		Mano		0.002[2]			1
29	Ervum lens	Seedling					0.85-2.00	Oxygen	20
30	Fagopyrum esculentum (buckwheat)	Germinating	25			41-306	0.8-1.0		21
31	F. esculentum (buckwheat, Sutton's, Simpson's)	Germinating	25	Chem			0.47-0.99		18
32	Glycine max (soybean)	Germinating		Mano			0.65		22
33	Gossypium hirsutum (cotton, Delfos-3506)	Resting	26	Mano		0.03-6.0	0.96-1.12	Moisture; storage or starvation	23
34	G. hirsutum (cotton, Cokers-200)	Resting	26	Mano		0.1-1.5	0.92-1.05	Moisture; storage or starvation	23

35	G. hirsutum (cotton, Oklahoma Triumph)	Resting	26	Mano		0.03-1.2	0.91-0.97	Moisture; storage or starvation	23
36	Helianthus annuus (sunflower)	Germinating		Mano			0.88		22
37		Resting	28	Mano			1.05		15
38		Germinating	18	Chem		92			6
39	H. annuus (sunflower, Russian)	Germinating	20	Chem		153-86[2]		Inorganic nutrition, salts	24
40	H. annuus (sunflower, Sutton's Giant Yellow)	Germinating	25	Chem			0.67-0.89 -0.55		18
41	H. annuus (sunflower, Simpson's Giant Yellow, Sutton's Giant Yellow)	Germinating	25	Chem		41-407	0.85-0.50		19
42	Hordeum distichum (barley)	Resting			0.005				25
43	H. distichum var. mutans (barley, Spratt, Archer)	Embryo	22	Chem		90-900-350[2]		Growth, development, maturation	26
44	H. vulgare (barley)	Resting	37.8	Chem		0.002-0.36[2]		Moisture	7
45	H. vulgare (barley, Chilean)	Resting		Mano		8.7			27
46		Embryo		Mano		62.6			27
47		Endosperm		Mano		3.6			27
48	Juglans regia (Persian walnut)	Resting	28	Mano			0.52		15
49	Juniperus virginiana (red cedar)	Resting	25	Mano		0.05	0.76		28
50		Germinating	25	Mano		6.6-25	0.84-0.97		28
51	Kajanus indicus (pigeon pea)	Resting	21	Chem		47-5.6		Growth, development, maturation	29
52	Lathyrus odoratus (sweet pea, Maxima Alba)	Moist	20	Mano	6.4[2]				30
53		Seedling	20	Mano	430-100[2]			Growth, development, maturation	30
54	L. odoratus (sweet pea, What Joy)	Germinating	25	Chem		11-110[2]	1.0		31
55		Germinating	25			46-102	0.9-0.98		21
56	L. odoratus (sweet pea, Sutton's, What Joy)	Germinating	25	Chem			1.0-0.85		18
57	Linum usitatissimum (flax)	Germinating	30	Mano			0.63		32
58		Resting	17	Mano	24		0.91		14
59		Germinating	18	Mano	214		0.55		14
60		Resting	37.8	Chem		0.03-1.5[2]		Moisture	7
61		Germinating	18	Mano			0.90-0.35	Growth, development, maturation	5
62	Lupinus albus (white lupine)	Germinating				50			17
63		Seedling	19	Chem		21			6
64		Seedling		Mano			0.80-1.12	Oxygen	6
65	L. luteus (Sutton's Dwarf Yellow)	Germinating	25	Chem			1.04-0.76		18
66	Medicago sativa (alfalfa)	Resting	18	Mano	38		1.08		14
67		Germinating	18	Mano	106		0.86		14
68	Mirabilis jalapa (four-o'clock)	Seedling	14	Chem		13			33
69	M. jalapa chlorina (four-o'clock)	Seedling	14	Chem		12			33
70	Oryza sativa (rice)	Seedling					0.86-2.3	Oxygen	6
71		Resting	37.8	Chem		0.004-0.35[2]		Moisture	7
72	O. sativa (rice, Bely)	Resting		Mano	0.04[2]		1.17		35
73		Moist		Mano	3.7[2]		1.74		35
74		Germinating		Mano	4.4[2]		1.81		35
75		Seedling		Mano	1.19[2]		1.00		35
76	O. sativa (rice, Blue Rose)	Resting	38	Chem		0.005-0.17[2]		Moisture	34
77	O. sativa (rice, Oobe)	Resting		Mano	0.03[2]		1.15		35
78		Moist		Mano	2.8[2]		1.96		35

/1/ Mano = manometric, Chem = chemical, Cond = conductometric. /2/ µl/100 mg dry weight/hour.

Values for rates of gaseous exchange are μl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp °C	Method[1]	Respiration Rate μl/100 mg/hr Q_{O_2}	Respiration Rate μl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
79	Oryza sativa (rice, Oobe) (concluded)	Germinating		Mano	4.9[2]		1.98		35
80		Seedling		Mano	1.06[2]		1.00		35
81	Phaseolus coccineus (scarlet runner)	Resting	28	Mano			1.75		15
82	P. vulgaris (kidney bean)	Germinating				65			17
83	Pinus insignis (Monterey pine)	Resting		Mano		0.0013[2]			1
84	Pisum sativum (garden pea)	Resting	28	Mano			1.00		15
85		Germinating				48			17
86		Seedling					0.83-2.3	Oxygen	6
87	P. sativum (garden pea, Early Sunrise)	Resting	16	Chem	6.5			Carbon dioxide	13
88	P. sativum (pea)	Intact	20	Chem		15-35	4.9-1.1	Oxygen	45
89	Polygonum scandens (climbing false buckwheat)	Moist	30				0.92		36
90		Moist	6				0.90		36
91	Prunus armeniaca (apricot)	Resting	28	Mano			0.53		15
92		Moist	25	Mano	7.0		0.65		4
93	P. cerasus (dwarf cherry, Morello)	Moist	25	Mano	6.4		0.87		4
94	P. domestica (plum)	Resting	28	Mano			0.80		15
95	P. domestica (plum, Blue Gage)	Moist	25	Mano	8.0		0.70		4
96	P. domestica (plum, Burbank)	Moist	25	Mano	4.7		0.91		4
97	P. persica (peach)	Moist	25	Mano	5.8		0.68		4
98	P. pumila (sand cherry)	Moist	25	Mano	5.5		0.88		4
99	Pyrus malus (apple, Newtown Pippin)	Resting	19			2.8[2]	0.86		37
100	Raphanus sativus (radish)	Resting	20	Mano	7.0		0.86		14
101		Germinating	20	Mano	103		0.58		14
102	Ricinus communis (castor bean)	Seedling	30	Mano	133		0.39		32
103		Endosperm	30	Mano	141		0.38		32
104		Resting	28	Mano			1.03		15
105		Seedling		Mano			0.54-1.10	Oxygen	6
106		Seedling	17	Chem		25			6
107		Germinating		Mano			0.70		22
108	R. communis (Simpson's Mirabilis, Gibson's Mirabilis)	Germinating	25	Chem			0.85-0.50		18
109	R. communis major (Sutton's)	Germinating	25	Chem		5.1-204	0.8-0.5		19
110	Rumex crispus (yellow curly dock)	Moist	25	Mano	6.7		1.16		4
111	Secale cereale (rye)	Seedling	18	Chem		12			6
112		Resting		Mano		0.008			1
113		Resting	38	Chem		0.002-0.11		Moisture	7
114	Setaria italica (millet)	Resting		Mano		0.002			1
115	Sinapis alba (white mustard)	Seedling					0.63		6
116	Soja max (soybean)	Germinating		Mano			0.93-0.87	Growth, development, maturation	5
117	Sorghum vulgare (sorghum)	Resting	37.8	Chem		0.011-0.32[2]		Moisture	7

118	Triticum aestivum (wheat)	Germinating		Mano			1.01		22
119	T. durum (wheat, Kubanka)	Seedling, etiolated		Cond		14.0-173[2]		Growth, development, maturation	38
120	T. vulgare (wheat)	Resting	37.8	Chem		0.004-0.23[2]		Moisture	7
121		Resting	24			0.023-0.14[2]		Moisture	40
122		Resting	65			0.34[2]			40
123		Resting	55			0.68[2]			40
124		Resting	35			0.028[2]			40
125		Resting	4			0.005[2]			40
126		Resting		Mano		0.27			1
127		Resting	38	Chem		0.005-0.16[2]		Moisture	34
128		Germinating	38	Chem		0.014-0.53[2]		Moisture	34
129		Seedling		Mano			0.98-3.7	Oxygen	6
130		Seedling	18	Chem		21			6
131	T. vulgare (wheat, Marquis)	Seedling	29	Mano	21-38[2]			Hormones	41
132		Seedling, etiolated		Cond		9.8-214[2]		Growth, development, maturation	38
133	T. vulgare (wheat, Minhardi)	Resting	28	Mano	0.05-10[2]			Moisture	39
134	T. vulgare (wheat, Poso)	Seedling, etiolated		Cond		7.4-193[2]		Growth, development, maturation	38
135	Tropaeolum majus (nasturtium, Sutton's Tall Scarlet)	Germinating	25	Chem			0.89-0.68		18
136	Vicia faba (broad bean)	Resting	28	Mano			0.99		15
137		Germinating			49				17
138		Seedling		Mano			1.05-2.3		6
139		Seedling	20	Chem		13		Oxygen	6
140	V. faba (broad bean, Sutton's Broad Windsor)	Germinating	25	Chem			1.23-0.82		18
141	V. sativa (common vetch)	Seedling					0.80-1.60	Oxygen	6
142		Seedling	18			26		Oxygen	6
143	Zea mais (corn)	Seedling		Mano			0.89-1.37	Oxygen	6
144		Seedling	18	Chem	15				6
145		Resting	37.8	Chem		0.01-0.46[2]		Moisture	10
146		Resting		Mano		1.7			27
147		Embryo		Mano		22.6			27
148		Endosperm		Mano		0.36			27
149		Resting		Mano		0.008[2]			1
150		Germinating	10	Mano		0.036-0.97[2]		Composition of varieties	43
151		Germinating	20	Mano		1.3-32[2]		Composition of varieties	43
152		Germinating	30	Mano		2.0-58[2]		Composition of varieties	43
153	Z. mais (corn, Sutton's Improved Japanese Striped)	Germinating	25			10-127	0.75-1.0		21
154	Z. mais (corn, Sutton's Early Sugar)	Germinating	25	Chem			1.0-0.73		18
155	Z. mais (corn, Hopeland Sweet)	Resting	22	Chem		0.24-1.2[2]		Moisture	44
156	Z. mais (corn, Reid's Yellow Dent)	Resting	22	Chem		0.26-1.4[2]		Moisture	44

/1/ Mano = manometric, Chem = chemical, Cond = conductometric. /2/ μl/100 mg dry weight/hour.

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164. RESPIRATION RATES: HIGHER PLANTS, ROOTS

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Achyranthes argentea	Intact	RT	Mano		4.7	1.04		1
2	Allium cepa (onion)	Segment	25	Mano	1390-1140[3]		0.99-1.07		2
3	Aster tripolium (aster)	Intact	20	Chem		69[3]			3
4	Beta vulgaris (beet)	Segment	23	Mano	5-13			Wounding	4
5		Intact	22			2.9-1.2		Storage or starvation	5
6	B. vulgaris (red beet)	Intact	25	Chem		0.9-0.6	0.8	Oxygen; storage or starvation	6
7		Segment	25	Mano	70-180-110[3]		1.01-0.85	Storage or starvation	7
8	B. vulgaris (sugar beet)	Intact	25			3.2-5.3-2.1	1.02-1.08	Storage or starvation	8
9	B. vulgaris (mangold)	Segment	25		43-260[3]		1.04	Storage or starvation	7
10	Borago officinalis (borage)	Intact	RT	Mano		4.5	0.77		1
11	Brassica napus (swede)	Segment	24	Mano	180[3]		0.88		9
12	B. rapa (turnip)	Intact	22	Chem		3.6			10
13		Intact	22			3.0-1.4		Storage or starvation	5
14	Bryonia dioica (bryony)	Intact	RT	Mano		1.5	0.90		1
15	Caltha palustris (cowslip)	Intact	19		79[3]				11
16	Cerinthe aspera	Intact	RT	Mano		5.6			1
17	Chrysanthemum sinense (chrysanthemum)	Intact	28	Mano			0.93		12
18	Convolvulus arvensis (bindweed)	Intact		Mano	27-64			Herbicides	13

19	Coronilla varia (crown vetch)	Nodule	28	Mano	200-800[3]		0.9-1.3		14
20	Crotalaria spectabilis (rattle box)	Nodule	28	Mano	230-800[3]		0.95-1.04		14
21	Dahlia sp (dahlia)	Intact	22			0.9-0.4		Storage or starvation	5
22	Daucus carota (carrot)	Intact	28	Chem		3.5			10
23		Intact	3.5	Chem		0.7			10
24		Segment	25	Mano	10-14			Storage or starvation	7
25		Intact	25	Chem		2.3-0.8		Oxygen; storage or starvation	6
26		Segment		Mano	16			Storage or starvation	15
27		Segment		Mano	26-4			pH; poisons	15
28		Intact	20	Chem		2.9-4.3	5.8-1.0	Oxygen	16
29	D. carota (carrot, Red Core Chantemay)	Intact	24	Chem		3.3-1.5	1.10-1.18	Storage or starvation	17
30		Intact	10	Chem		1.5-0.5	1.08-1.01	Storage or starvation	17
31		Intact	0.5	Chem		0.44-0.22	0.92-1.16	Storage or starvation	17
32	Erodium moschatum (filaree)	Intact	RT	Mano		11.8	0.83		1
33	Fumaria capreolata	Intact	RT	Mano		9.7	0.90		1
34	Geranium robertianum (geranium)	Intact	RT	Mano		10.3	0.86		1
35	Gossypium herbaceum (cotton, Roseum)	Intact	38	Chem		380-73[3]		Growth, development, maturation	18
36	Hordeum vulgare (barley, Plumage Archer)	Intact	20	Cond		484-740[3]		Oxygen	19
37	H. vulgare (barley, Sacramento)	Excised	23.5	Chem		37			20
38		Segment	24	Mano			0.94-1.0-0.9	Growth, development, maturation	21
39	Impatiens sp (balsam)	Intact	38	Chem		625-104[3]		Growth, development, maturation	18
40	Ipomoea batatas (sweet potato)	Intact				3.0-3.6		Storage or starvation	22
41		Intact	22			2.0-0.9		Storage or starvation	5
42		Segment	25	Mano	96		1.0		23
43	I. batatas (sweet potato, Porto Rico)	Intact	15	Chem		1.9			24
44		Intact	25	Chem		4.0			24
45		Intact	35	Chem		6.2			24
46	I. batatas (sweet potato, Triumph)	Intact	15	Chem		1.4			24
47		Intact	25	Chem		3.2			24
48		Intact	35	Chem		5.6			24
49	I. grandiflora (morning glory)	Excised	20	Mano	220[3]				25
50	Lamium album (dead nettle)	Intact	18-19		262[3]				11
51	Lathyrus odoratus (sweet pea)	Excised	20	Mano	160[3]				25
52	Lespedeza stipulacea (Korean clover)	Nodule	28	Mano	130-550[3]		0.94-1.4		14
53	Lycopersicum esculentum (tomato)	Excised	28	Mano	30-1120[3]			Accessory growth factors	27
54	L. esculentum (tomato, Bonny Best)	Excised	25	Mano	600-800[3]		1.0		26
55	Malva parviflora (mallow)	Intact	RT	Mano		8.4	0.83		1
56	M. silvestris (high mallow)	Intact	RT	Mano		10.2	0.90		1
57	Melilotus alba (sweet clover)	Nodule	28	Mano	380-660[3]		0.95-1.09		14
58	Mentha aquatica (mint)	Intact	18-19		154[3]				11
59	Mercurialis annua (mercury)	Intact	RT	Mano		4.7	0.82		1
60	Oryza sativa (rice)	Intact	15-18		180-230[3]			Growth, development, maturation	11
61	Oxalis corniculata (creeping laurel)	Intact	RT	Mano		14.7	1.0		1
62	Pastinaca sativa (parsnip)	Intact	22	Chem		2.7			10
63		Intact	1.5	Chem		1.1			10
64		Intact	22			4.5-2.1		Storage or starvation	5
65		Intact		Mano		31			28

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical, Cond = conductometric. /3/ µl/100 mg dry weight/hour.

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
66	Pistia sp (water lettuce)	Intact		Chem		85[3]	1.05		29
67	Pyrus malus (apple)	Intact	14	Chem		26[3]	0.73		30
68	Raphanus raphanistrum (wild radish)	Intact	RT	Mano		11.9	0.87		1
69	R. sativus (radish)	Intact	28	Mano			0.99		12
70	R. sativus aegyptiacus (radish)	Intact	25	Chem		<u>3.1</u>-21		Wounding	31
71	Soja max (soybean)	Nodule	28	Mano	60-430[3]		1.0-2.0		14
72	Stachys hirta (woundwort)	Intact	RT	Mano		11.8	0.81		1
73	Taraxacum officinale (dandelion)	Intact		Chem		0.04-0.1[3]	0.94-1.24	Herbicides	32
74	Thrincia tuberosa	Intact	RT	Mano		4.1	0.85		1
75	Triticum vulgare (wheat)	Intact	15-18		234-346[3]			Growth, development, maturation	11
76		Intact	20	Chem	<u>10</u>-253			Inorganic nutrition, salts	33
77	Urtica membranacea (nettle)	Intact	RT	Mano		4.7	0.87		1
78	Vicia faba major (broad bean)	Excised	26	Mano			1.46		34
79	V. sativa (common vetch)	Nodule	28	Mano	170-780[3]		0.98-1.3		14
80	V. villosa (hairy vetch)	Nodule	28	Mano	230-900[3]		1.0-1.4		14
81	Vigna sinensis (cowpea)	Nodule	28	Mano	71-580[3]		1.0-1.1		14

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical, Cond = conductometric. /3/ µl/100 mg dry weight/hour.

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165. RESPIRATION RATES: HIGHER PLANTS, STEMS

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Acacia melanoxylon (blackwood acacia)	Intact	RT	Mano		10.5	0.82		1
2	Acer rubrum (red maple)	Xylem	25	Mano	3.7-2.3			Growth, development, maturation	2
3		Cambium	25	Mano	22.4			Growth, development, maturation	2
4		Phloem	25	Mano	16.9			Growth, development, maturation	2
5	Acorus calamus (sweetflag)	Rhizome		Mano		22			3
6		Rhizome	25	Chem		3.7			4
7	Aesculus sp (horse chestnut)	Bud	20			9.7			5
8	Aloe spinosa (spinulosa)	Shoot	24	Mano	3.1		0.82		6
9		Shoot	10	Mano	1.5				6
10	Asclepias incarnata (milkweed)	Rhizome	25	Chem		3.7			4
11	Asparagus albus (asparagus)	Intact	RT	Mano		11.3	0.96		1
12	A. officinalis (asparagus)	Shoot	30	Chem		915-254[3]		Storage or starvation	8
13	A. officinalis (asparagus, Mary Washington)	Intact	24	Chem		35.4-13.2	1.04-0.95	Storage or starvation	7
14		Intact	10	Chem		9.7-3.6	1.03-0.86	Storage or starvation	7
15		Intact	0.5	Chem		3.0-2.0	0.98-0.95	Storage or starvation	7
16	Borago officinalis (borage)	Intact	RT	Mano		6.1	0.81		1
17	Bryonia dioica (bryony)	Intact	RT	Mano		8.5	0.91		1
18	Cabomba aquatica (fanwort)	Shoot	20	Chem	49[3]				9
19	Cakile maritima (sea-rocket)	Shoot	20	Chem		50[3]			10
20	Calamintha nepeta (savory)	Shoot	24	Mano	35.2				6
21	Caltha palustris (cowslip)	Intact	20	Mano	120[3]				11
22	Carnegiea gigantia (giant cactus)	Shoot	25			2.0-0.5		Storage or starvation	12
23	Cassiope hypnoides (cassiope)	Shoot	40	Chem		47			13
24		Shoot	20	Chem		9.7			13
25		Shoot	0	Chem		2.1			13
26	C. tetragona (cassiope)	Shoot	40	Chem		44			13
27		Shoot	20	Chem		14			13
28		Shoot	0	Chem		1.5			13
29	Ceratophyllum demersum (hornwort)	Shoot	20	Chem	81[3]				3
30	Cereus grandiflorus (cereus)	Shoot	5	Mano	0.4				6
31	C. languinosus (cereus)	Shoot	9	Mano	0.7				6
32	C. macrogonus (cereus)	Shoot	12	Mano	0.3				6
33	Clematis cirrhosa (clematis)	Intact	RT	Mano		12.4			1
34	Convallaria sp (lily-of-the-valley)	Bulb	19			8.6			5
35	C. polygonatum (lily-of-the-valley)	Rhizome		Mano		18			14
36	Convolvulus arvensis (bindweed)	Rhizome		Mano	28-61			Herbicides	15
37	Crassula arborescens (crassula)	Shoot	14	Mano	2.2		0.89		6
38		Shoot	31	Mano	6.5		0.88		6
39		Shoot	14 & 18	Mano	2.6-2.6		0.89-0.24	Light or photoperiod	6
40	Cynara scolymus (artichoke)	Tuber	25	Chem		1.4-0.8		Oxygen; storage or starvation	16
41		Tuber, segment	25	Mano	160[3]				17
42	Dahlia variabilis (dahlia)	Bulb	25	Mano			0.99		56
43	Diapensia lapponica	Shoot	40	Chem		60			13
44		Shoot	20	Chem		23			13

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical. /3/ µl/100 mg dry weight/hour.

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control of endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
45	Diapensia lapponica (concluded)	Shoot	0	Chem		2			13
46	Elodea canadensis (waterweed)	Shoot	20	Mano	90[3]				11
47	E. crispa (waterweed)	Shoot	20	Chem	63[3]				9
48	E. densa (waterweed)	Shoot	20	Chem	74[3]				9
49		Shoot	20	Chem	40-200[3]		0.11-1.05		18
50	Empetrum nigrum (crowberry)	Shoot	40	Chem		39			13
51		Shoot	20	Chem		9			13
52		Shoot	0	Chem		1			13
53	Encelia farinosa (brittlebush)	Shoot	25			23-17		Storage or starvation	12
54	Euphorbia mamillaris (spurge)	Shoot	18 & 24	Mano		6.5-1.6	1.04-0.34	Light or photoperiod	6
55	E. rhipsaloides (spurge)	Shoot	18	Mano	7.1				6
56	Faba vulgaris (horse bean)	Shoot	12	Mano	9.7				6
57	Fraxinus nigra (black ash)	Xylem	25	Mano		31.3-1.4		Growth, development, maturation	2
58		Phloem	25	Mano		16.7		Growth, development, maturation	2
59		Cambium	25	Mano		22		Growth, development, maturation	2
60	Fumaria capreolata (fumitory)	Intact	RT	Mano		8.8	0.88		1
61	Galanthus nivalis (snowdrop)	Shoot	13	Mano	7.8				6
62	Geranium robertianum (geranium)	Intact	RT	Mano		6.5	0.94		1
63	Gladiolus sp (gladiola)	Corm	23	Chem		8.5[3]			19
64	Gossypium herbaceum (cotton, Roseum)	Intact	38	Chem		168-42[3]		Growth, development, maturation	20
65	Hedera helix (English ivy)	Shoot	20	Mano		23.6	0.93		6
66	Helianthus annuus (sunflower, Sutton's Giant Yellow)	Shoot	5	Chem		76[3]			21
67		Shoot	10	Chem		141[3]			21
68		Shoot	25	Chem		483[3]			21
69	Hippuris vulgaris (mare's-tail)	Intact	16	Chem		25			3
70	Hottonia palustris (featherfoil)	Shoot	20	Chem	150[3]				9
71	Impatiens sp (balsam)	Intact	38	Chem		270-59[3]		Growth, development, maturation	20
72	Ipomoea batatas (sweet potato)	Tuber	30	Chem		1.4-7.0-2.4		Storage or starvation	22
73	I. grandiflora (morning glory)	Intact	20	Mano	250[3]				11
74	Kleinia articulata (candle plant)	Intact	25	Mano	2.4-0.5			Storage or starvation	23
75		Shoot	18-24	Mano		3.0-0.3	0.99-0.18	Light or photoperiod	6
76	Lathyrus odoratus (sweet pea)	Shoot	20	Mano	350[3]				11
77		Intact	20	Mano	160[3]				11
78	Lavatera olbia (tree mallow)	Intact	RT	Mano		11.3			1
79	Lupinus albus (white lupine)	Shoot	12		7.4				6
80	Lycopersicum esculentum (tomato)	Segment	30	Mano	75-300[4]			Oxygen	27
81		Segment	30	Mano	300-120[4]			Hormones	27
82		Phloem	30	Mano	105-58[4]			Herbicides	27

83		Phloem	30	Mano	156[4]			Carbohydrates	27
84	L. esculentum (tomato, Bonny Best)	Segment	28	Mano	420-350[3]		0.91-0.95	Inorganic nutrition, salts	25
85		Segment	27	Mano	119[5]				26
86		Phloem	27	Mano	98[5]				26
87	L. esculentum (tomato, Kondine Red)	Shoot	25	Chem		24-19		Healthy vs diseased	24
88	Malva parviflora (mallow)	Intact	RT	Mano		9.7	0.85		1
89	Mamillaria elephantidens (cactus)	Shoot	12	Mano	0.6				6
90	Mercurialis annua (mercury)	Intact	RT	Mano		5.6	0.82		1
91	Mesembryanthemum deltoides (midday-flower)	Shoot	31	Mano		5.4	0.87		6
92		Shoot	23	Mano		7.2	0.93		6
93		Shoot	8	Mano		2.9	0.88		6
94		Shoot	23 & 31	Mano		5.4-4.8	0.87-0.85	Light or photoperiod	6
95	M. nodiflorum	Intact	RT	Mano		3.9	1.0		1
96	Mirabilis jalapa (four-o'clock)	Shoot	15 & 18	Mano		17.5-12.0	0.98-1.00	Light or photoperiod	6
97	Myriophyllum hippuroides (parrot's feather)	Shoot	20	Chem	89[3]				9
98	M. verticillatum (parrot's feather)	Shoot	20	Chem	132[3]				9
99	Nicotiana glauca x N. langsdorfii (tobacco)	Callus	30	Mano	380[3]		1.0		28
100	N. tabacum (tobacco, Burley)	Bud	25	Mano	4.4-8.3[4]			Healthy vs diseased	29
101	Nuphar advena (spatter-dock)	Rhizome	25	Chem		3.0			4
102	Opuntia cylindrica (prickly pear)	Shoot		Mano			0.58-0.06	Light or photoperiod	6
103		Shoot	13	Mano	0.7				6
104	O. dejecta (prickly pear)	Shoot	15	Mano	2.3-1.7			Growth, development, maturation	6
105	O. intermedia (prickly pear)	Shoot	16	Mano	1.1				6
106	O. maxima (prickly pear)	Shoot	15	Mano	1.5		0.90-0.03	Light or photoperiod	6
107	O. monacantha (prickly pear)	Shoot		Mano			0.93-0.24	Light or photoperiod	6
108		Shoot	26	Mano	9.6-4.1			Growth, development, maturation	6
109	O. tomentosa (prickly pear)	Shoot	25	Mano		3.6-0.5	0.73-0.41	Growth, development, maturation	6
110		Shoot	24	Mano		1.1-0.2	0.49-0.05	Light or photoperiod	6
111	Oxalis cernua (Bermuda buttercup)	Rhizome	RT	Mano		5	1.18		1
112	O. corniculata (creeping laurel)	Intact	RT	Mano		15.4	0.97		1
113	O. stricta (wood sorrel)	Shoot	RT	Mano		13.8	0.99		1
114	Pereskia aculeata (lemon vine)	Shoot	24	Mano		15.5-10.4	0.91-0.84		6
115	Phaseolus vulgaris (bean, Burpee's Stringless Green Pod)	Shoot, etiolated	15	Chem		270[3]			30
116		Shoot, etiolated	25	Chem		580[3]			30
117		Shoot, etiolated	35	Chem		430[3]			30
118	P. vulgaris (bush bean, Stringless Green Pod)	Shoot		Chem	10[4]				31
119	P. vulgaris (bean, California Red Kidney)	Intact	30	Mano	28-710[3]		0.9-1.1	Herbicides; metabolic poisons	32
120	P. vulgaris (bean, Black Valentine)	Shoot	24	Chem		150-190[3]		Herbicides	33
121	Phyllocactus grandiflorus (cactus)	Shoot	20-24	Mano		6.2-5.0	0.96-0.78	Growth, development, maturation	6
122		Shoot	19	Mano		1.0-0.3	0.78-0.09	Light or photoperiod	6

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical. /3/ µl/100 mg dry weight/hour. /4/ µl/sq cm/hour. /5/ µl/mg N/hour.

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
123	Picea excelsa (Norway spruce)	Shoot	15	Mano	4.4				6
124		Shoot	19	Mano	25.0-6.3			Growth, development, maturation	6
125	Pisum sativum (garden pea, Alaska)	Segment	25	Mano	532-334[3]		1.07-0.98	Storage or starvation	35
126		Segment	25	Mano	532-677[3]		1.07-0.98	Hormones	35
127		Segment, etiolated	25	Mano	552-660			Hormones	36
128	Polygonum persicaria (lady's-thumb)	Intact	RT	Mano		6.9	0.82		1
129	Potamogeton perfoliatus (pondweed)	Shoot	20	Chem	67[3]				9
130	Potentilla reptans (cinquefoil)	Intact	RT	Mano		11.0	0.83		1
131	Proserpinaca palustris (mermaid-weed)	Shoot	20	Chem	62[3]				9
132	Prunus laurocerasus (cherry laurel)	Shoot	22.5	Chem		14.4-2.6		Storage or starvation	37
133	Psoralea bituminosa (scurf-pea)	Intact	24	Mano		57-11	1.06-0.80	Growth, development, maturation	38
134		Intact	RT	Mano		9.6			1
135	Ptelea trifoliata (hop-tree)	Intact	RT	Mano		7.7	0.88		1
136		Intact	15	Mano		26-9	0.92-0.88	Growth, development, maturation	38
137	Pyrus malus (apple, Jonathon)	Intact	6	Chem		2.3-4.6		Precooling	39
138	P. malus (apple, Haraldson)	Intact	6	Chem		1.7-3.7		Precooling	39
139	P. malus (apple, Charlamoff)	Intact	6	Chem		1.6-2.6		Precooling	39
140	P. malus (apple, Duchess)	Intact	6	Chem		1.5-2.4		Precooling	39
141	P. malus (apple, Hibernal)	Intact	6	Chem		1.2-2.0		Precooling	39
142	P. malus (apple, McIntosh)	Intact	6	Chem		1.7-3.8		Precooling	39
143	Quercus coccifera (oak)	Segment	21	Mano		31-11	0.91-0.83	Growth, development, maturation	38
144	Raphanus raphanistrum (wild radish)	Intact	RT	Mano		10.5	0.87		1
145	Rhipsalis salicor (cactus)	Shoot	18	Mano		3.1	1.04		6
146	Ricinus communis (castor bean)	Shoot	20	Mano		19.2	0.96		6
147	Rochea falcata	Shoot	23	Mano		0.03	0.92		6
148	Rubia peregrina (madder)	Intact	RT	Mano		6.3			1
149	Rumex lunaria (dock)	Intact	RT	Mano		10			1
150	R. pulcher (fiddle-dock)	Intact	RT	Mano		11.8	0.85		1
151	Ruscus hypophyllum (butcher's broom)	Intact	RT	Mano		1.7	0.58		1
152	Saccharum officinarum (sugar cane)	Intact	28	Chem		27-4[3]		Growth, development, maturation	40
153	Sagittaria latifolia (arrowhead)	Rhizome	25	Chem		4.1			4
154	Salicornia herbacea (glasswort)	Shoot	22	Chem		30[3]			10
155	Salix herbacea (willow)	Shoot	20	Chem		23.4			13
156		Shoot	10	Chem		9.1			13
157		Shoot	0	Chem		2.5			13
158	Sambucus nigra (European elder)	Intact	RT	Mano		9.8			1
159	Saxifraga oppositifolia (purple mountain saxifrage)	Shoot	40	Chem		25			13
160		Shoot	20	Chem		7.1			13
161		Shoot	0	Chem		0.87			13
162	S. tridactylites (saxifrage)	Intact	20	Mano	100[3]				11

163	Scirpus articulatus (bulrush)	Shoot	30	Chem		23-12		Growth, development, maturation	41
164		Scape	30	Chem		13-27		Oxygen	41
165	S. validus (soft-stem bulrush)	Rhizome	25	Chem		2.8			4
166	Sedum acre (mossy stonecrop)	Shoot	25	Mano	7.2-7.1		0.96-0.84	Light or photoperiod	6
167		Shoot	23	Mano	10.2-7.1			Growth, development, maturation	6
168	S. album (white stonecrop)	Shoot	14	Mano	5.7		0.96		6
169	S. carneum (stonecrop)	Intact	18 & 25	Mano		6.7-11.0	0.95-1.0	Growth, development, maturation	6
170		Intact	24	Mano		11.0-6.8	1.0-0.82	Light or photoperiod	6
171	S. dendroideum (stonecrop)	Shoot	12 & 18	Mano	1.9-3.1		1.0-0.41	Light or photoperiod	6
172	S. reflexum (stonecrop)	Intact	19 & 26	Mano		4.0-12.5	0.83-0.97	Growth, development, maturation	6
173		Intact	23 & 31	Mano		12.0-8.7	0.98-0.88	Light or photoperiod	6
174	S. telephium (garden-orpine)	Intact	24 & 31	Mano		6.8-21.0	0.95-1.01	Growth, development, maturation	6
175		Intact	18 & 24	Mano		6.8-3.7	0.95-0.60	Light or photoperiod	6
176	Sempervivum tectorum (houseleek)	Shoot	42	Mano	17				6
177		Shoot	26	Mano	10				6
178		Shoot	13	Mano	2.5				6
179	Smyrnium olusatrum	Intact	RT	Mano		4.7			1
180	Solanum tuberosum (potato)	Tuber	25	Chem		0.4-0.3		Oxygen; storage or starvation	16
181		Tuber	20	Chem		0.5-3.2		Wounding	47
182		Tuber	29	Chem		140[3]			48
183		Tuber, segment	29	Mano		80[3]			48
184		Tuber, segment	25	Mano	7.2-16.0		0.87-1.03	Storage or starvation	49
185		Tuber, segment	23	Chem		10.5-16.5		pH	50
186		Tuber, segment	23	Chem		6-22[3]		Inorganic nutrition, salts	51
187		Tuber, segment	28	Mano	35[3]		1.0		52
188	S. tuberosum (potato, Arran Comrade)	Tuber	20	Chem		1.4-0.36		Growth, development, maturation	54
189		Tuber	20	Chem		0.36-0.46		Healthy vs diseased	54
190		Tuber, sprouting	20	Chem		0.30-0.56		Growth, development, maturation	54
191	S. tuberosum (potato, Farrukhabad)	Tuber	13	Chem		1.9-0.8	0.98-0.99	Growth, development, maturation	46
192	S. tuberosum (potato, Idaho)	Tuber, segment	30	Mano	0.85-2.3			pH and buffers	53
193	S. tuberosum (potato, King Edward)	Tuber	15	Chem		0.25-2.0	1.0-1.26	Metabolic poisons; storage or starvation	44
194		Tuber	1	Chem		0.1-0.4		Storage or starvation	45
195	S. tuberosum (potato, Maryland Certified Irish Cobbler)	Tuber	22	Chem		0.6-0.25		Storage	42
196	S. tuberosum (potato, McCormack)	Tuber	22	Chem		1.5-0.22		Storage	42

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical. /3/ µl/100 mg dry weight/hour.

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
197	Solanum tuberosum (potato, McCormack) (concluded)	Tuber	2.5	Chem		0.4			42
198	S. tuberosum (potato, Rural)	Tuber	24	Chem		0.6-0.3	1.02-0.75	Storage or starvation	7
199		Tuber	10	Chem		0.2-0.15	0.86-0.99	Storage or starvation	7
200		Tuber	0.5	Chem		0.07-0.15	0.45-0.66	Storage or starvation	7
201	S. tuberosum (potato, Russet Burbank)	Tuber	22	Chem		0.5			42
202		Tuber	2.5	Chem		0.2			42
203		Tuber	22	Chem		3.7-0.6		Wounding	42
204	S. tuberosum (potato, Russett Rural)	Tuber	-0.83	Chem		0.1			43
205		Tuber	0.22	Chem		0.2			43
206		Tuber	3	Chem		0.1			43
207		Tuber	11.5	Chem		0.3			43
208	Sparganium eurycarpum (bur-reed)	Rhizome	25	Chem	2.3				4
209	Spartium junceum (Spanish broom)	Intact	RT	Mano		16	0.8		1
210	Stachys hirta (woundwort)	Intact	RT	Mano		9.8	0.81		1
211	Syringa vulgaris (lilac)	Cambium		Mano			1.29-1.38		55
212	Taxus baccata (yew)	Shoot	28	Mano			0.97		56
213	Tilia pubescens (linden)	Cambium		Mano			1.99-2.23		55
214	Triticum sativum (wheat)	Shoot	13	Mano		29	0.98		6
215		Shoot	8	Mano		19	1.03		6
216	T. vulgare (wheat, Marquis)	Shoot	30	Mano		61-34[3]		Healthy vs diseased	57
217	T. vulgare (wheat, Minnesota 169 Bluestem)	Shoot	30	Chem		61-78[3]		Freezing	57
218	Typha latifolia (cat-tail)	Rhizome	25	Chem		2.4			4
219	Urtica membranacea (nettle)	Intact	RT	Mano		8.8	0.88		1
220	Vaccinium sp (cranberry, Howes)	Shoot	24	Chem		34-17		Growth, development, maturation	58
221		Bud	24	Chem		55			58
222	Valeriana officinalis (garden-heliotrope)	Intact	20	Mano	150[3]				11
223	Vicia faba (broad bean)	Intact	RT	Mano		6.2			1
224		Shoot	21	Mano		62.6	0.90		1
225		Shoot, etiolated	21	Mano		48.8	0.87		1
226	V. sativa (common vetch)	Intact	RT	Mano		14.9	0.86		1
227	Zea mais (corn, Albino)	Shoot	30	Mano		760[3]		Light or photoperiod	59
228		Shoot	30	Mano		500-1000[3]		Carbohydrates	59
229	Z. mais (corn, Green)	Shoot	30	Mano		710-870[3]		Carbohydrates	59

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical. /3/ µl/100 mg dry weight/hour.

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166. RESPIRATION RATES: HIGHER PLANTS, LEAVES

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Abutilon striatum (flowering maple)	Intact	20	Chem		1.2[3]			1
2	Acacia melanoxylon (blackwood acacia)	Tendril, phyllode, or cladode	RT	Mano		11.9	0.66		2
3	Acanthus mollis (bear's breech)	Intact	22	Mano		18	0.77		3
4	Acer pseudoplatanus (sycamore-maple)	Intact		Chem		61[4]			4
5		Intact	10	Chem		33			5
6	A. pseudoplatanus atropurpureum (maple)	Intact	16	Chem		23			5
7	A. pseudoplatanus cupreum (maple)	Intact	16	Chem		24			5
8	A. pseudoplatanus luteo-virescens (maple)	Intact	10	Chem		28			5
9	A. pseudoplatanus lutescens (maple)	Intact	16	Chem		23			5
10	A. pseudoplatanus purpureum (maple)	Intact	16	Chem		25			5
11	Achyranthes argentea	Blade	RT	Mano		9.4	0.71		2
12	Achras sapota (sapodilla)	Intact	20	Chem		1.3[3]			1
13	Acokanthera spectabilis (wintersweet)	Intact	15	Mano		6	0.94		6
14		Intact, red	15	Mano		8	0.71		6

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical, Cond = conductometric. /3/ µl/sq cm/hour. /4/ µl/100 mg dry weight/hour.

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
15	Actaea spicata (baneberry)	Intact	18			1.4-2.4[3]		Light or photoperiod	7
16	Aesculus hippocastanum (horse chestnut)	Intact	12	Chem		49			5
17		Intact, white	12	Chem		26			5
18		Intact	25	Mano		77	0.98		8
19		Intact	14	Mano		25	1.01		8
20		Intact	0	Mano		6	0.97		8
21	Ajuga reptans (bugle-weed)	Intact	20	Chem		1.5[3]			9
22	Alchemilla minor (lady's-mantle)	Intact	20	Chem		4-8[3]			10
23	A. vatteri (lady's-mantle)	Intact	20	Chem		8[3]			10
24	Allium cepa (onion)	Bulb	22			0.9-0.6		Storage or starvation	12
25	A. cepa (onion, Yellow Globe)	Bulb	22	Chem		2.1			11
26	Ampelopsis hederacea (michx)	Blade	19	Mano		57-22	0.86-0.61	Growth, development, maturation	13
27	Amygdalus communis (almond)	Intact	14	Mano		29	1.00		6
28		Intact, red	14	Mano		30	0.78		6
29	Anacardium occidentale (cashew)	Intact		Chem		69-24		Growth, development, maturation	14
30	Antennaria alpina (everlasting)	Intact	40	Chem		63			15
31		Intact	20	Chem		20			15
32		Intact	0	Chem		1.5			15
33	Antirrhinum majus (snapdragon)	Intact	20	Mano		16	0.88		16
34	Aralia sp	Intact	28.5	Chem		15-36	0.73		17
35	Arbutus unedo (strawberry tree)	Intact	22	Chem		5[3]			18
36	Aristida junciformis (needlegrass)	Intact	39	Mano		11[3]			19
37	Asparagus albus (asparagus)	Tendril, phyllode, or cladode	RT	Mano		22.3	0.78		2
38	Aspidistra sp (aspidistra)	Intact	25	Mano			0.94		20
39	A. elatior (aspidistra)	Intact	20	Chem		0.6[3]			1
40	Aster tripolium (aster)	Intact	20	Chem		143[4]			21
41	Atriplex hortensis (garden orach)	Intact	18	Chem		44			5
42	A. hortensis chlorina (garden orach)	Intact	19	Chem		37			5
43	A. hortensis atropurpurea (garden orach)	Intact	19	Chem		38			5
44	Aucuba sp (aucuba)	Intact	25	Mano			1.11		20
45	A. japonica (aucuba)	Intact	22.5	Chem		12.0-6.8		Storage or starvation	22
46	Bambusa nana (bamboo)	Intact	22.5	Chem		22.0-8.5-22		Storage or starvation	22
47	Begonia haageana (begonia)	Intact	17	Chem		34[3]			23
48	B. rex (begonia)	Intact	20	Mano		30			16
49	B. semperflorens (begonia)	Intact	20	Chem		1.8[3]			1
50	B. tuberhybrida (begonia)	Intact	36			13[3]	0.79		24
51		Intact	5			0.9[3]			24
52	Beta vulgaris (beet)	Intact	27	Chem		23			25
53	Betula nana (birch)	Intact	20	Chem		66			15

54		Intact	10	Chem		26			15
55		Intact	20			11[3]			26
56		Intact	10			5[3]			26
57	B. verrucosa (birch)	Intact	20	Chem	6[3]				10
58	Borago officinalis (borage)	Blade	RT	Mano		6.9	0.65		2
59		Petiole	RT	Mano		3.7	0.77		2
60	Bougainvillea sp (bougainvillea)	Intact	29	Mano			0.92		27
61	Brassica alba (brussels sprouts)	Intact	28	Mano			0.92		27
62	Bryonia dioica (bryony)	Blade	RT	Mano		13.2	0.65		2
63		Petiole	RT	Mano		9.4	0.87		2
64		Tendril, phyllode, or cladode	RT	Mano		11.3	1.02		2
65		Intact	20	Mano		76-11	0.90-0.60	Growth, development, maturation	13
66	Bryophyllum calycinum (life plant)	Segment	20	Mano	13-11-14		0.82-0.37-1.2		28
67	Calophyllum inophyllum	Intact	40			12.7[3]			29
68		Intact	30			6.6[3]			29
69		Intact	20			3.6[3]			29
70		Intact	10			2.0[3]			29
71	Caltha palustris (marsh marigold)	Intact	20	Mano	100[4]				30
72	Canna indica (Indian shot)	Intact	22	Mano		14	0.72		16
73	Carpinus betulus (European hornbeam)	Intact	28	Mano			0.97		27
74	Cassia fistula (pudding-pipe tree)	Intact	40			21[3]			29
75		Intact	30			8.1[3]			29
76		Intact	20			4.1[3]			29
77		Intact	10			2.0[3]			29
78	Cassine maurocenia (Hottentot cherry)	Intact	19	Mano		33	0.96		6
79		Intact, red	19	Mano		43	0.89		6
80	Castanea sp (chestnut)	Intact	25	Mano			1.02-0.92	Growth, development, maturation	20
81	Catalpa bignonioides aurea (common catalpa)	Intact	14	Chem		18			5
82	C. bignonioides koehnei (common catalpa)	Intact	14	Chem		25			5
83	C. kaempferi (catalpa)	Intact	18	Chem		30			5
84	C. kaempferi atropurpurea (catalpa)	Intact	17	Chem		43			5
85	Celsia (figwort)	Intact	22			31	0.80		3
86	Cerinthe aspera	Blade	RT	Mano		6.3	0.66		2
87	Chamaenerium latifolium (river-beauty)	Intact	20	Chem		34			15
88		Intact	10	Chem		13			15
89		Intact	0	Chem		6.6			15
90		Intact	20			13.4[3]			26
91		Intact	10			5.3[3]			26
92		Intact	0			2.7[3]			26
93	Cheiranthus cheiri (wallflower)	Intact	20			19	0.79		3
94	Cistus albidus (rock rose)	Intact	24	Chem		20[3]			18
95	C. monspeliensis (rock rose)	Intact	32	Chem		31[3]			18
96	Citrus aurantium (lime)	Intact	20	Chem		3.0[3]			1
97	C. limonia (lemon, Eureka)	Intact		Mano	7.7-9.5[3]				31

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical, Cond = conductometric. /3/ µl/sq cm/hour. /4/ µl/100 mg dry weight/hour.

166. RESPIRATION RATES: HIGHER PLANTS, LEAVES (Continued)

Values for rates of gaseous exchange are μl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate μl/100 mg/hr Q_{O_2}	Respiration Rate μl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
98	Citrus sinensis (orange, Washington Navel)	Intact		Mano	9.6-12.9[3]				31
99	Clematis cirrhosa (Clematis)	Blade	RT	Mano		17.8			2
100		Petiole	RT	Mano		8.9			2
101	Coffea arabica (coffee, Arabian)	Intact	20	Chem		1.5[3]			1
102	Colutea arborescens (bladder senna)	Blade	17	Mano		74-19	0.87-0.70	Growth, development, maturation	13
103	Convallaria majalis (lily-of-the-valley)	Intact	17			19[3]			33
104	Corylus avellana (hazel)	Intact	15			0.4-1.2[3]		Light or photoperiod	7
105		Intact		Chem		29			5
106	C. avellana atropurpurea (hazel)	Intact		Chem		24			5
107	Corynocarpus laevigata (New Zealand laurel)	Intact	26	Mano			1.13		34
108	Cotyledon ramosissima (cotyledon)	Intact	25	Mano			1.05		20
109	Crassula arborescens (crassula)	Bud		Mano	7.2				35
110		Intact		Mano	3.9-1.1			Growth, development, maturation	35
111	C. portulacea (crassula)	Intact	25	Mano			0.94		20
112	Croton sp (croton)	Intact, white	35	Chem		233-144[4]		Storage or starvation	36
113	Dentaria bulbifera (toothwort)	Intact	18			23-34[3]		Light or photoperiod	7
114	Dioscorea cayennensis (yam)	Intact	19	Chem		70[3]			23
115	D. divaricata (yam)	Intact	27	Chem		10			25
116	Echinocystis fabacea (wild cucumber)	Intact	25	Chem		5[3]			37
117	Elodea canadensis (waterweed)	Intact		Mano, Chem			8.4		38
118	Eragrostis curvula (love-grass)	Intact	34	Mano		14[3]			19
119	Erica arborea (heath)	Intact	24	Chem		5[3]			18
120	Eriobotrya japonica (loquat)	Intact	25	Chem		9.3[3]			39
121	Erodium moschatum (filaree)	Blade	RT	Mano		17.2	0.64		2
122		Petiole	RT	Mano		8.5			2
123	Eucalyptus globulus (eucalyptus)	Intact	19	Mano		8.5	0.80		8
124		Intact	28				0.94		27
125	Eugenia michelii (pitanga)	Intact	16	Mano		8	0.81		6
126		Intact, red	16	Mano		11	0.79		6
127	Euphorbia mamillaris (spurge)	Intact	25	Mano			1.01		20
128	Evonymus japonica (spindle tree)	Intact	28	Mano			1.02		27
129		Intact	31	Mano		41	0.94		8
130		Intact	15	Mano		13	0.97		8
131		Intact	0	Mano		1.5	0.97		8
132	Fagus silvatica (European beech)	Intact	20	Chem		1-5[3]			40
133		Intact	21	Chem		34			5

134	F. silvatica purpurea macrophylla (beech)	Intact	20	Chem		32			5
135	Ficus benjamina (fig)	Intact	20	Chem		1.6[3]			1
136	Fragaria sp (strawberry)	Intact	24.5	Chem		10-5[3]		Growth, development, maturation	41
137	Fraxinus excelsior (ash)	Intact	20	Chem		1-6[3]		Light or photoperiod	40
138		Intact	16			15[3]			7
139	Fumaria capreolata (fumitory)	Blade	RT	Mano		21.3	0.89		2
140		Petiole	RT	Mano		16.4	1.00		2
141	Geranium robertianum (geranium)	Blade	RT	Mano		13.9	0.72		2
142		Petiole	RT	Mano		4.4	0.91		2
143	G. sanguineum (geranium)	Intact	10			7-13[3]		Light or photoperiod	7
144	Gladiolus sp (gladiola)	Intact	24	Mano		18	0.64		3
145	G. gandavensis (gladiola)	Intact	24	Mano		18	0.64		16
146	Gossypium herbaceum (cotton, Roseum)	Intact	38	Chem		224-94[4]		Growth, development, maturation	42
147	Hedera helix (English ivy)	Intact	32	Mano		40	1.00		8
148		Intact	18	Mano		18	1.00		8
149		Intact	25	Mano	50-80			Growth, development, maturation	43
150		Intact	28	Mano			1.20-1.00	Growth, development, maturation	27
151	H. helix var. rotundifolia (English ivy)	Intact	22.5	Chem		13.6-5.1		Storage or starvation	22
152	Helianthus annuus (sunflower)	Intact		Cond		66-147[4]		Growth, development, maturation	44
153		Intact	25	Chem		9-3[3]		Storage or starvation	37
154		Intact	20	Chem		5.8[3]			23
155		Intact	31	Chem		16.6[3]			23
156		Intact	42	Chem		24.5[3]			23
157	Heracleum sibiricum (cow-parsnip)	Intact	10			14-63[3]		Light or photoperiod	7
158	Hibiscus rosa-sinensis (Chinese hibiscus)	Intact	20	Chem		1.3[3]			1
159	Hordeum vulgare (barley)	Intact	23	Mano		26.6	0.85		2
160		Intact, etiolated	23	Mano		21.6	0.83		2
161		Intact	25	Chem		500-250[4]		Growth, development, maturation	45
162		Intact	25	Chem		58-23		Storage or starvation	46
163		Intact	25	Chem		76-15	1.2-0.8	Storage or starvation	47
164		Intact	24	Mano, Cond	32-17		1.1-1.8		48
165	Hydrangea hortensis (hydrangea)	Intact	25	Chem		4.5[3]			37
166	Hypoxis rooperi (stargrass)	Intact	27	Mano		13[3]			19
167	Ilex aquifolium (holly)	Intact	21	Mano		12			49
168	Impatiens sp (balsam)	Intact	38	Chem		312-120[4]		Growth, development, maturation	42
169	Ipomoea grandiflora (morning glory)	Intact	20	Mano	220[4]				30
170	Iris germanica (iris)	Intact	22.5	Chem		12-13.6-5		Storage or starvation	22
171	Kleinia radicans (candle plant)	Intact	25		4-9-2			Storage or starvation	50
172	Lactuca sativa (lettuce)	Intact	30	Chem		390-120[4]		Storage or starvation	51
173	L. sativa (lettuce, Imperial 44)	Intact	24	Chem		3.3-2.6	1.12-0.99	Storage or starvation	52
174		Intact	10	Chem		1.3-0.73	1.09-0.93	Storage or starvation	52
175		Intact	0.5	Chem		0.8-0.35	0.84-0.98	Storage or starvation	52
176	Laserpitium latifolium (laserwort)	Intact	14			6-11[3]		Light or photoperiod	7
177	Lathyrus odoratus (sweet pea)	Intact	20	Mano	170[4]				30

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical, Cond = conductometric. /3/ µl/sq cm/hour. /4/ µl/100 mg dry weight/hour.

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
178	Laurus nobilis (laurel)	Intact	22.5	Chem		8.5-3.42		Storage or starvation	22
179		Intact	13	Chem		10[3]			18
180	Lavatera olbia (tree mallow)	Blade	RT	Mano		10.5			2
181		Petiole	RT	Mano		5.7			2
182		Intact	21	Mano		76-21	0.80-0.69	Growth, development, maturation	13
183		Intact	22			39			3
184	Lemna minor (duckweed)	Intact	25	Mano		300[4]			53
185	Ligustrum japonicum (privet)	Intact	26	Mano		68	0.84		2
186		Intact, white	26	Mano		53	0.80		2
187	L. lucidulum	Intact	25	Mano	120-50			Growth, development, maturation	43
188	Lolium italicum (darnel)	Intact	19-20		104[4]				54
189	Lonicera xylosteum (honeysuckle)	Intact	17			8-17[3]		Light or photoperiod	7
190	Lycopersicum esculentum (tomato)	Intact	22			3.2-8.5[3]			57
191	L. esculentum (tomato, 46-31)	Intact	28	Mano	210[4]				56
192	L. esculentum (tomato, Bonny Best)	Segment	28	Mano	390-430[4]	0.96-0.91		Inorganic nutrition, salts	55
193	L. esculentum (tomato, Gem)	Intact	28	Mano	260[4]				56
194	L. esculentum (tomato, Improved Wasath Beauty)	Intact	28	Mano	190[4]				56
195	L. esculentum (tomato, John Baer)	Intact	28	Mano	230[4]				56
196		Segment	30	Mano	42-46		1.28-1.13	Inorganic nutrition, salts	59
197	L. esculentum (tomato, Longred)	Intact	28	Mano	210[4]				56
198	L. esculentum (tomato, Michigan State Forcing)	Intact	27	Mano	260-320[4]			Light or photoperiod	58
199	L. esculentum (tomato, Rutgers)	Intact	28	Mano	210[4]				56
200	Mahonia sp (mahonia)	Intact	25	Mano			0.95		20
201	Malva parviflora (mallow)	Blade	RT	Mano		31.9	0.84		2
202		Petiole	RT	Mano		8.1	0.97		2
203	M. silvestris (high mallow)	Blade	RT	Mano		12.3	0.71		2
204	Melandrium rubrum	Intact	18	Chem		3.0[3]			60
205	Melianthus major (honey flower)	Intact	16	Mano		26	0.66		3
206	Mercurialis annua (mercury)	Blade	RT	Mano		10.2	0.73		2
207		Petiole	RT	Mano		8.6	0.97		2
208		Blade	17	Mano		69-18	0.97-0.90	Growth, development, maturation	13
209	Mesembryanthemum nodiflorum (midday-flower)	Blade	RT	Mano		3.1	0.86		2
210	Mirabilis jalapa (four-o'clock)	Intact	15	Chem		25			5
211	M. jalapa chlorina (four-o'clock)	Intact	15	Chem		19			5
212	Myrtillus nigra	Intact	9			2-6[3]		Light or photoperiod	7
213	Myrtus communis (myrtle)	Intact	20	Chem		10[3]			18
214	Narcissus poeticus (poets' narcissus)	Bulb					0.96-2.36	Oxygen	49

215	Nicotiana glauca x N. langsdorfii (tobacco)	Segment	25	Mano	330-170[4]		1.27-1.43	Growth, development, maturation	61
216	N. tabacum (tobacco)	Segment	25	Mano	220-150[4]			Growth, development, maturation	32
217		Segment	25	Mano	43.0-41.5		0.98-0.98	Healthy vs diseased	32
218	Oenothera biennis (evening primrose)	Blade	18	Mano		24-12	0.83-0.70	Growth, development, maturation	13
219	Olea europaea (olive)	Intact	22	Mano		32-13	0.78-0.75	Growth, development, maturation	13
220		Intact	14	Chem		36[3]			18
221	Opuntia versicolor (prickly pear)	Intact	21	Chem		14-36			62
222		Intact	35	Chem		15	0.70		62
223		Intact	45	Chem		33			62
224		Intact	55	Chem		21			62
225		Intact	65	Chem		6			62
226	Ornithogalum arabicum (Star-of-Bethlehem)	Intact	20			6	0.89		3
227	Oxalis acetosella (wood laurel)	Intact	20	Chem		1[3]			9
228		Intact	18	Chem		3.1[3]			60
229		Intact	20			1.2[3]			26
230	O. cernua (Bermuda buttercup)	Blade	RT	Mano		8.5	0.96		2
231		Petiole	RT	Mano		7.5	1.6		2
232	O. corniculata (creeping laurel)	Blade	RT	Mano		20.7	0.84		2
233		Petiole	RT	Mano		14.6	0.93		2
234	O. stricta (wood sorrel)	Blade	RT	Mano		18.9	0.86		2
235		Petiole	RT	Mano		14.4	1.03		2
236	Oxyria digyna (mountain sorrel)	Intact	20	Chem		26			15
237		Intact	10	Chem		16			15
238		Intact	0	Chem		5			15
239	Panicum maximum (guinea grass)	Intact	31	Mano		5[3]			19
240	Papaver rhoeas (corn poppy)	Intact	21	Mano		33			16
241	Paris quadrifolia (herb-paris)	Intact	18			5-9[3]		Light or photoperiod	7
242	Passiflora caerulea (passion-flower)	Blade	22	Mano		73-21	0.94-0.86	Growth, development, maturation	13
243	Pelargonium hortorum (common bedding geranium)	Intact	36	Mano		32[3]	0.85		24
244		Intact	5	Mano		0.7[3]			24
245	P. zonale (horseshoe geranium)	Intact	22.5	Chem		29-13.6-29		Storage or starvation	22
246		Intact	20	Chem		2.3[3]			1
247		Intact	28	Mano			1.01		27
248	Pennisetum clandestinum (Kikuyu grass)	Intact	25			43-13-38		Storage or starvation	63
249	Penstemon gentianoides (beard-tongue)	Intact	24	Mano		30	0.76		16
250	Petasites albus (sweet coltsfoot)	Intact	26	Chem		5.8[3]			23
251	Phaseolus vulgaris (kidney bean)	Intact	26	Mano	26-57				64
252		Intact	26	Mano	6-64			pH; substrate; poisons-fumigants, insecticides	64
253	Phillyrea angustifolia (phillyrea)	Intact	28	Chem		10[3]			18
254	P. media (phillyrea)	Intact	28	Chem		10[3]			18
255	Phleum pratense (timothy)	Intact	21-26		124[4]				54
256	Phoenix dactylifera (date palm)	Intact	20	Chem		4.5[3]			1
257	Photinia glabra (photinia)	Intact	15	Mano		7	0.90		6

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical, Cond = conductometric. /3/ µl/sq cm/hour. /4/ µl/100 mg dry weight/hour.

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
258	Photinia glabra (photinia) (concluded)	Intact, red	15	Mano		10	0.77		6
259	Phragmites communis (common reed)	Intact	22.5	Chem		31-12		Storage or starvation	22
260		Intact	19-20		54[4]				54
261	Phyllocactus grandiflorus (cactus)	Intact	25	Mano			1.04		20
262	Pinus canariensis (pine)	Intact	29	Mano		42	0.90		8
263	P halepensis (Aleppo pine)	Intact	16			10	0.81		8
264	P. maritama (cluster pine)	Intact	36	Mano		5	0.87		8
265		Intact	20	Mano		12	0.84		8
266		Intact	0	Mano		2	0.83		8
267	P. pinea (stone pine)	Intact	24	Mano		12	0.83		8
268		Intact	14	Mano		6.9	0.82		8
269	P. silvestris (Scotch pine)	Intact	28	Mano			0.95-0.96	Growth, development, maturation	27
270		Intact	35	Mano		47	0.87		8
271		Intact	24	Mano			0.80		8
272	Pistacia lentiscus (pistachio)	Intact	16	Chem		15[3]			18
273	Pisum sativum (garden pea, Alaska)	Intact	27	Mano	430-680[4]			Light or photoperiod	58
274	Plantago major (common plantain)	Intact	20	Chem		5-7[3]			10
275	Plumeria alba (plumeria)	Intact	20	Chem		1.4[3]			1
276	P. lutea (plumeria)	Intact	20	Chem		25[3]			23
277	P. rubra (frangipani)	Intact	20	Chem		2.6[3]			1
278	Polygonatum multiflorum (Solomon's-seal)	Intact	22.5	Chem		18.7-5.0-13.6		Storage or starvation	22
279	Polygonum cuspidatum (jointweed)	Intact	22.3	Chem		25.5-11		Storage or starvation	22
280	P. persicaria (lady's-thumb)	Blade	RT	Mano		17.6	0.73		2
281		Blade	16	Mano		33-18	0.79-0.76	Growth, development, maturation	13
282	P. viviparum (knotweed)	Intact	20	Chem		53			15
283		Intact	10	Chem		27			15
284		Intact	0	Chem		9			15
285	P. weyrichii (knotweed)	Intact	25	Chem		7.9[3]			23
286	Populus canadensis (poplar)	Intact		Chem		19			5
287	P. canadensis aurea (poplar)	Intact		Chem		17			5
288	Potentilla reptans (cinquefoil)	Blade	RT	Mano		31.9	0.67		2
289		Petiole	RT	Mano		10.7	0.83		2
290	Primula auricula (primrose)	Intact	36			17[3]	0.79		24
291		Intact	5			0.9[3]			24
292	P. obconica (primrose)	Intact	20	Chem		1.6[3]			1
293	Prunus cerasifera (cherry-plum)	Intact	16	Mano		26	0.80		6
294		Intact, red	16	Mano		17	0.70		6
295	P. laurocerasus (cherry laurel)	Intact	22.5	Chem		4.6			65
296		Intact	22.5	Chem		20-3.4-13.6		Storage or starvation	66
297	P. lusitanicus (Portugal laurel)	Intact	22.5	Chem		15.3-6.8-10		Storage or starvation	22

298	P. padus (European bird cherry)	Intact	11			0.04-1.10[3]		Light or photoperiod	7
299	Psoralea bituminosa (scurf-pea)	Blade	24	Mano		76-22	0.90-0.81	Growth, development, maturation	13
300		Blade	RT	Mano		11.3			2
301		Petiole	RT	Mano		5.7			2
302	Ptelea trifoliata (hop-tree)	Blade	RT	Mano		9.6	0.67		2
303		Petiole	RT	Mano		7.0	0.72		2
304		Blade	15	Mano		35-9.6	0.87-0.67	Growth, development, maturation	13
305		Intact	16	Chem		26			5
306	P. trifoliata aurea (hop-tree)	Intact	15	Chem		22			5
307	Pyrus malus (apple, McIntosh)	Intact	33	Chem		8.6-43.0[3]		Moisture	67
308	P. malus (apple, Stayman's Winesap)	Intact	33	Chem		7.6-36.0[3]		Moisture	67
309	Quercus coccifera (oak)	Intact	21	Mano		44-13	0.87-0.79	Growth, development, maturation	13
310	Q. ilex (holly oak)	Intact	24	Chem		20[3]			18
311	Ranunculus glacialis (buttercup)	Intact	20	Chem		28			15
312		Intact	10	Chem		19			15
313		Intact	0	Chem		5.1			15
314	R. pygmaeus (dwarf buttercup)	Intact	30	Chem		93			15
315		Intact	10	Chem		16			15
316		Intact	0	Chem		8.7			15
317	Raphanus raphanistrum (wild radish)	Blade	RT	Mano		13.3	0.73		2
318		Petiole	RT	Mano		6.2	0.86		2
319	Raphiolepis ovata	Intact	14	Mano		4	1.01		6
320		Intact, red	14	Mano		5	0.81		6
321	Reseda alba (white mignonette)	Intact	20	Mano		30	0.70		16
322	Rhamnus alaternus (buckthorn)	Intact	29	Chem		31[3]			18
323	Rheum rhaponticum (rhubarb)	Segment	30	Mano		29	1.17		68
324	Rhododendron fargesii (rhododendron)	Intact	22.5	Chem		13.6-5.1		Storage or starvation	22
325	Robinia pseudacacia (false acacia)	Intact	28	Mano			0.96		27
326	Rosa sp (rose)	Intact	14	Mano		23	0.93		6
327		Intact, red	14	Mano		31	0.91		6
328	Rubia peregrina (madder)	Blade	RT	Mano		12.6			2
329	Rubus idaeus (European raspberry)	Intact	13			2-10[3]		Light or photoperiod	7
330		Intact		Chem		61[4]			4
331	R. saxatilis (bramble)	Intact	13			12[3]		Light or photoperiod	7
332	Rumex acetosa (garden sorrel)	Blade	RT	Mano		21.6	0.76		2
333		Petiole	RT	Mano		11.5	0.88		2
334	R. acetosella (field sorrel)	Intact	20	Chem		5[3]			9
335	R. lunaria (sorrel)	Blade	RT	Mano		13.6			2
336		Petiole	RT	Mano		8.5			2
337	R. pulcher (fiddle-dock)	Blade	RT	Mano		14.7	0.76		2
338		Petiole	RT	Mano		3.3	0.80		2
339	Ruscus hypophyllum (butcher's broom)	Intact, cladode	15	Mano		4-2		Growth, development, maturation	13
340		Tendril, phyllode, or cladode	RT	Mano		2.6	0.55		2
341	Ruta angustifolia (rue)	Intact	48	Mano		160	0.73		8
342		Intact	17	Mano		16	0.73		8
343	R. graveolens (rue)	Intact	28	Mano			1.00		27
344	Salix glauca (willow)	Intact	20			17[3]			26

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical, Cond = conductometric. /3/ µl/sq cm/hour. /4/ µl/100 mg dry weight/hour.

166. RESPIRATION RATES: HIGHER PLANTS, LEAVES (Continued)

Values for rates of gaseous exchange are μl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate μl/100 mg/hr Q_{O_2}	Respiration Rate μl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
345	Salix glauca (willow) (concluded)	Intact	10			9.4[3]			26
346		Intact	0			2.9[3]			26
347		Intact	20	Chem		78			15
348		Intact	10	Chem		45			15
349		Intact	0	Chem		13			15
350	Salvia grahamii (sage)	Intact	14	Mano		19	0.88		6
351		Intact, red	14	Mano		25	0.84		6
352	Sambucus nigra (European elder)	Blade	RT	Mano		16			2
353		Intact	20	Chem		3[3]			9
354	Sapium bolinense	Intact	19	Chem		90[3]			23
355	Saponaria officinalis (bouncing-bet)	Intact	21			45	0.82		3
356		Intact	21	Mano		29	0.72		16
357	Saxifraga cernua (saxifrage)	Intact	20	Chem		17.8			15
358		Intact	10	Chem		5.6			15
359		Intact	0	Chem		2.4			15
360	Scilla hemisphoerica (squill)	Intact	20			4	0.78		3
361	S. peruviana (Cuban lily)	Intact	20	Mano		4	0.78		16
362	Secale cereale (rye)	Intact	25	Mano		44			69
363		Intact	15	Mano		26			69
364	Sedum acre (stonecrop)	Intact	25	Mano			1.07		20
365	S. dendroideum (stonecrop)	Intact		Mano	9.3-4.3			Growth, development, maturation	35
366		Bud		Mano	21.9				35
367	S. praealtum (stonecrop)	Intact				11-4-6	1.3-0.45-2.1	Storage or starvation	70
368	Senecio bupleuroides (groundsel)	Intact	36	Mano		22[3]			19
369	S. cruentus (groundsel)	Intact	20	Chem		2.2[3]			1
370	S. grandifolius (groundsel)	Intact	25	Chem		51[3]			23
371	S. petasites (velvet groundsel)	Intact	20	Chem		2.1[3]			1
372	S. silvaticus (groundsel)	Intact	20	Chem		7[3]			9
373	Sibbaldia procumbens	Intact	20	Chem		60			15
374		Intact	10	Chem		19			15
375	Sinapis alba (white mustard)	Intact	20	Chem		8[3]			9
376	Smilax aspera (greenbrier)	Intact	20	Chem		5[3]			18
377	Smyrnium olusatrum	Blade	RT	Mano		14.6			2
378		Petiole	RT	Mano		12.1			2
379	Solanum nigrum (black nightshade)	Blade	16	Mano		34-10	0.78-0.67	Growth, development, maturation	13
380	S. tuberosum (potato)	Intact	48	Chem		137			71
381		Intact	30	Chem		41			71
382		Intact	10	Chem	10				71
383	Solidago virgaurea (goldenrod)	Intact	15			3-11[3]		Light or photoperiod	7
384	Sorbus aucuparia (European mountain-ash)	Intact	16			2[3]			7

385	Sorghum vulgare (sorghum)	Intact		Chem		1.2-0.2[4]		Growth, development, maturation	72
386	Sparganium ramosum (bur-reed)	Intact	22.5	Chem		32-12		Storage or starvation	22
387	Sparmannia africana (African hemp)	Intact	20	Chem		1.8[3]			1
388	Spartium junceum (Spanish broom)	Blade	RT	Mano		17	0.71		2
389	Spinacia oleracea (spinach)	Intact	20	Chem		9[3]			10
390		Intact	20	Chem		4.7-7.2	0.87-0.82	Oxygen	73
391		Segment	30	Mano	62-41		1.0-0.74	Storage or starvation	74
392		Segment	30	Mano	43-41		0.93-0.73	pH	74
393	S. oleracea (spinach, Longstanding Bloomsdale)	Intact	24	Chem		16.2-12.8	0.94-0.83	Storage or starvation	52
394		Intact	10	Chem		4.2-2.0	0.90-0.86	Storage or starvation	52
395		Intact	0.5	Chem		1.5-5.8	0.85-0.73	Storage or starvation	52
396	Spiraea opulifolia (spiraea)	Blade	RT	Mano		16.0	0.65		2
397		Petiole	RT	Mano		11.5	0.71		2
398		Blade	17	Mano		49-19	0.88-0.74	Growth, development, maturation	13
399	S. ulmaria (spiraea)	Intact	11			9-10[3]		Light or photoperiod	7
400	Spironema fragrans	Intact	20	Chem		3.0[3]			1
401	Stachys hirta (woundwort)	Blade	RT	Mano		13.3	0.80		2
402		Petiole	RT	Mano		5.6	0.91		2
403	Statice limonium (sea-lavender)	Intact	20	Chem		112[4]			21
404		Intact	20	Chem		61[4]			21
405	Stelechocarpus burahol	Intact	40		10[3]				29
406		Intact	30		5.6[3]				29
407		Intact	20		2[3]				29
408		Intact	10		0.8[3]				29
409	Stellaria nemorum (chickweed)	Intact	18	Chem		3.3[3]			60
410	Syringa vulgaris (lilac)	Intact	28	Mano			1.00		27
411		Intact	32	Mano		28	0.99		8
412		Intact	24	Mano		7.5	0.94		8
413		Intact	18	Mano		3.7	0.98		8
414	Taraxacum officinale (dandelion)	Intact	19	Mano		48.5	0.95		75
415	Taxus baccata (yew)	Intact	46	Mano		55	0.89		8
416		Intact	34	Mano		23	0.80		8
417		Intact	16	Mano		6	0.86		8
418		Intact	28	Mano			0.98-0.89	Growth, development, maturation	27
419	Teucrium scorodonia (wood-sage)	Intact	20	Mano		90			76
420	Thea sinensis (tea)	Segment	36	Mano	80-46		1.27-0.74	Storage or starvation	77
421		Segment	36	Chem		16.4			77
422	Themeda triandra var. glauca	Intact	27	Mano		7[3]			19
423	T. triandra var. trachyspathea	Intact	38	Mano		5.6[3]			19
424	Thrincia tuberosa	Blade	RT	Mano		8.8	0.74		2
425	Tilia platyphylla (linden)	Intact	20	Chem		1.6[3]			1
426	Tradescantia viridis (wandering jew)	Intact	29	Mano			1.01		27
427	Tricholaena rosea (natal-grass)	Intact	19	Mano		8.7[3]			19
428	Trifolium pratense (red clover)	Intact				80-212[4]	0.86-0.89	Healthy vs diseased	79
429	Triticum compactum (wheat, Little Club)	Intact	20	Chem		15-10-18-14		Storage or starvation	80
430	T. sativum (wheat)	Intact	25	Mano		40.2	0.97		2

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical, Cond = conductometric. /3/ μl/sq cm/hour. /4/ μl/100 mg dry weight/hour.

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp[1] °C	Method[2]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
431	Triticum sativum (wheat) (concluded)	Intact, etiolated	25	Mano		37.5	0.98		2
432	T. vulgare (wheat, Marquis)	Intact	20	Mano	4.2-8.6[3]			Healthy vs diseased	81
433		Intact	22	Mano	2-14[3]			Healthy vs diseased	78
434		Intact	22	Mano	20-60		1.3-1.05	Healthy vs diseased	82
435	T. vulgare (wheat, Minhardi)	Intact	28	Mano			0.93		27
436	Tulipa sp (tulip, Le Notre)	Bulb	20			4.6-2.8-8.6[4]	1.2-1.1-2.6	Storage or starvation	83
437	T. europaea (tulip)	Intact	13	Mano	9.0				35
438	T. gesneriana (tulip, Pride of Haarlem)	Bulb	25	Mano	1.4-1.9			Carbon dioxide	84
439	Typha latifolia (cat-tail)	Intact	22.5	Chem		26-15-19		Storage or starvation	22
440	Ulmus montana (elm)	Intact	16	Chem		24			5
441	U. montana atropurpurea (elm)	Intact	16	Chem		23			5
442	Urtica membranacea (nettle)	Blade	RT	Mano		10.8	0.69		2
443		Petiole	RT	Mano		6.9	0.85		2
444	Valeriana officinalis (garden-heliotrope)	Intact	20	Mano	180[4]				30
445	Verbascum thapsus (common mullein)	Intact	23	Mano		38	0.84		16
446	Veronica beccabunga (speedwell)	Intact	16-17		104[4]				54
447	Viburnum opulus (European cranberry bush)	Intact	13			2-7[3]		Light or photoperiod	7
448	V. tinus (laurestinus)	Intact	12	Chem		5[3]			18
449		Intact	16	Mano		5	0.82		6
450		Intact, red	16	Mano		5	0.66		6
451	Vicia faba (broad bean)	Blade	RT	Mano		11.1			2
452		Petiole	RT	Mano		4.1			2
453	V. sativa (common vetch)	Blade	RT	Mano		30.1	0.75		2
454		Petiole	RT	Mano		16.7	0.88		2
455		Tendril, phyllode, or cladode	RT	Mano		25.7	0.90		2
456	Viscaria alpina (alpine campion)	Intact	40	Chem		58			15
457		Intact	20	Chem		23			15
458		Intact	0	Chem		4			15
459	Vitis vinifera (wine grape)	Blade		Chem		81[4]			4
460	Yucca gloriosa (yucca)	Intact	22.5	Chem		8.5-3.3		Storage or starvation	22
461	Zea mais (corn)	Intact	26	Mano		68.3	0.99		2
462		Intact, etiolated	26	Mano		54.1	0.97		2
463		Intact		Chem		4.3-0.1[4]		Growth, development, maturation	72

/1/ RT = room temperature. /2/ Mano = manometric, Chem = chemical, Cond = conductometric. /3/ µl/sq cm/hour. /4/ µl/100 mg dry weight/hour.

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167. RESPIRATION RATES: HIGHER PLANTS, FLOWERS

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Acanthus mollis (bear's breech)	Sepal	24	Mano		63-41-28	1.06-1.03-.88	Growth, development, maturation	1
2		Petal	26	Mano		56-37-32	.79-.83-.94	Growth, development, maturation	1
3		Stamen	21	Mano		33-52-30	.97-.91-.71	Growth, development, maturation	1
4		Pistil	21	Mano		31-27-25	.89-.87-.90	Growth, development, maturation	1

/1/ Mano = manometric, Chem = chemical.

167. RESPIRATION RATES: HIGHER PLANTS, FLOWERS (Continued)

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
5	Agave attenuata (century plant)	Stamen	15	Mano		24-21	0.78-0.74	Growth, development, maturation	1
6		Pistil	14	Mano		34-13-11	.92-.68-.69	Growth, development, maturation	1
7	Aloe arborescens (aloe)	Stamen	17	Mano		36-21-11		Growth, development, maturation	1
8		Pistil	17	Mano		26-23-25	0.93-0.94	Growth, development, maturation	1
9	Anemone japonica (anemone)	Bud	19	Chem		37			2
10	Antirrhinum majus (snapdragon)	Petal	23	Mano		82-70-34	1.15-1.13-1.00	Growth, development, maturation	1
11		Stamen	24	Mano		81-106-76		Growth, development, maturation	1
12		Stamen	20	Mano		31	0.95		1
13		Pistil		Mano		61	1.0		1
14		Intact	28	Mano			0.98		3
15	Aquilegia vulgaris (columbine)	Sepal	20	Mano	150[2]				4
16		Petal	20	Mano	200[2]				4
17		Stamen	20	Mano	190[2]				4
18		Ovule	20	Mano	190[2]				4
19	Arisaema sp (jack-in-the-pulpit)	Pollen	25	Mano	480[2]				5
20	Arum italicum (wild ginger)	Spadix	18		2800				6
21	A. maculatum	Spadix	30	Mano	1560-3180-780[2]		1.09-0.87	Growth, development, maturation	7
22	Begonia rex (begonia)	Pistil	20	Mano		31			1
23		Stamen	20	Mano		43			1
24		Sepal	20	Mano		39			1
25		Petal	20	Mano		37			1
26	Bellis perennis (English daisy)	Intact	28	Mano			1.02		3
27	Bougainvillea sp (bougainvillea)	Intact	35	Chem		102-138[2]		Light or photoperiod	8
28	Cacalia verbascifolia (Indian-plantain)	Intact	18	Chem		34			2
29	Caltha palustris (cowslip)	Petal	20	Mano	210[2]				4
30		Stamen	20	Mano	330[2]				4
31		Ovule	20	Mano	360[2]				4
32	Camellia japonica (camellia)	Pollen	20	Mano	780[2]		1.34	Carbohydrates	5
33	C. sasanqua (camellia)	Pollen	15	Mano	480[2]			Carbohydrates	5
34	Canna sp (canna)	Intact	35	Chem		41-41[2]		Light or photoperiod	8
35	C. indica (Indian shot)	Petal	22	Mano		27	0.79		1
36		Stamen	22	Mano		65	0.72		1
37		Pistil	22	Mano		45	0.78		1
38	Celsia cretica (figwort)	Petal	24	Mano		127-54	1.04-0.97	Growth, development, maturation	1
39		Sepal	24	Mano		113-78	1.03-1.00	Growth, development, maturation	1
40		Pistil	22			56	1.00		9
41		Stamen	22			54	0.86		9
42	Centropogon lucyanus	Intact	28	Mano			0.99		3
43	Cheiranthus cheiri (wallflower)	Pistil	20			97	1.01		9
44		Stamen	20			84	0.91		9
45	Coelogyne mooreana (orchid)	Intact	25	Mano			0.9-0.95	Pollination; hormones	10
46	Cucumis sativus (cucumber)	Pistil	22	Mano		48-43-29		Growth, development, maturation	1

47	Cyclamen persicum (cyclamen)	Intact	28	Mano			1.03		3
48	Cymbidium lowianum (cymbidium)	Intact	25	Mano	64-122[2]		0.9-1.0	Pollination; hormones	10
49	Dahlia variabilis (dahlia)	Petal	28	Mano			0.94		3
50	Delphinium sinense (larkspur)	Intact	28	Mano			0.94		3
51	Gladiolus sp (gladiola)	Stamen	24	Mano		27	0.77		9
52		Pistil	24	Mano		71	0.90		9
53	G. gandavensis (gladiola)	Petal	24	Mano		15	0.72		1
54		Stamen	24	Mano		27	0.77		1
55		Pistil	24	Mano		71	0.90		1
56	Helianthus annuus (sunflower)	Inflorescence	10	Chem		57-43[2]		Growth, development, maturation	11
57	Hibiscus rosa-sinensis (Chinese hibiscus)	Petal	26	Mano		130-86-38	1.06-1.04 -0.96	Growth, development, maturation	1
58		Sepal	24	Mano		75-44-29	0.81-0.90-0.94	Growth, development, maturation	1
59	Hippeastrum sp (amaryllis)	Pollen	20	Mano	650[2]				5
60	Jasminum nudiflorum (jasmine)	Intact	28	Mano			1.01		3
61	Lathyrus odoratus (sweet pea)	Petal	20	Mano	330[2]				4
62		Filament	20	Mano	160[2]				4
63		Ovary	20	Mano	300[2]				4
64		Ovule	20	Mano	420[2]				4
65	Lavatera olbia (tree mallow)	Pistil	22			89			9
66		Stamen	22			58			9
67		Sepal	22	Mano		62			1
68		Petal	22	Mano		30			1
69		Pistil	20	Mano		82-77	0.93-0.94	Growth, development, maturation	1
70		Petal	24	Mano		77-65	0.90-0.84		1
71		Stamen	24	Mano		138-106	0.90-0.84		1
72	Lilium auratum (golden-banded lily)	Pollen	25	Mano	1060[2]		1.01		5
73	L. elegans (lily)	Pollen	25	Mano	610[2]				5
74	L. hansonii (lily, Golden Turk's-cap)	Pollen	25	Mano	340[2]				5
75	L. longiflorum (Easter lily)	Pollen	25	Mano	930[2]				5
76	L. longiflorum (lily)	Anther	25	Mano		73-31		Growth, development, maturation	12
77	L. philippinensis (lily)	Pollen	25	Mano	1140[2]		1.04		5
78	L. philippinensis (lily, Iwado)	Pollen	25	Mano	950[2]				5
79	L. philippinensis (lily, Nahate)	Pollen	25	Mano	520[2]				5
80	L. croceum (orange lily)	Stamen				56-21	1.14-0.98	Growth, development, maturation	13
81		Pistil				58-19	1.06-1.12	Growth, development, maturation	13
82	Melianthus major (honey flower)	Stamen	20	Mano		62-50-57	0.94-0.89-0.90	Growth, development, maturation	1
83		Pistil	20	Mano		52-75	0.89-0.97	Growth, development, maturation	1
84		Pistil	16	Mano		54	0.94		9
85		Stamen	16	Mano		35	0.80		9
86	Narcissus tazetta (polyanthus narcissus)	Stamen	17	Mano		56-51-26		Growth, development, maturation	1
87		Pistil	17	Mano		23-24-33		Growth, development, maturation	1
88	Nerium sp (oleander)	Intact	35	Chem		76-102[2]		Light or photoperiod	8
89	Ornithogalum arabicum (star-of-Bethlehem)	Stamen	20	Mano		49-29-20	0.91-0.84-0.80	Growth, development, maturation	1
90		Pistil	20	Mano		34-30-47	0.90-0.94-1.00	Growth, development, maturation	1
91		Pistil	20			40	1.04		9
92		Stamen	20			22	0.93		9
93	Paeonia albiflora (peony)	Pollen	25	Mano	700[2]				5

/1/ Mano = manometric, Chem = chemical. /2/ µl/100 mg dry weight/hour.

167. RESPIRATION RATES: HIGHER PLANTS, FLOWERS (Concluded)

Values for rates of gaseous-exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
94	Papaver orientale (oriental poppy)	Pollen	25	Mano	520[2]				5
95	P. rhoeas (corn poppy)	Sepal	21	Mano		39			1
96		Petal	21	Mano		37			1
97		Stamen	21	Mano		104			1
98		Pistil	21	Mano		69			1
99	P. somniferum (opium poppy)	Bud	17	Mano		8.2	1.01		14
100	Pelargonium zonale (horseshoe geranium)	Sepal	24	Mano		77-64-70	1.00-1.04-1.07	Growth, development, maturation	1
101	Penstemon gentianoides (beard-tongue)	Sepal	24	Mano		57	0.84		1
102		Petal	24	Mano		40	0.87		1
103		Pistil	24	Mano		69	0.94		1
104		Stamen	24	Mano		60	0.89		1
105	Philadelphus sp (mock orange)	Intact	28	Mano			1.03		3
106	Pinus densiflora (Japanese red pine)	Pollen	25	Mano	160[2]				5
107	Primula obconica (primrose)	Intact	28	Mano			0.96		3
108	Reseda alba (white mignonette)	Stamen	20	Mano		59	0.86		1
109	Rosa sp (rose)	Intact	28	Mano			1.04		1
110	Sambucus nigra (European elder)	Intact	28	Mano			0.95		3
111	Saponaria officinalis (bouncing-bet)	Pistil	21			95	2.1		9
112		Stamen	21			95	1.9		9
113		Pistil	21	Mano		55	1.24		1
114		Stamen	21	Mano		57	1.06		1
115		Sepal	21	Mano		69	1.02		1
116		Petal	21	Mano		53	0.93		1
117	Sauromatum guttatum	Spadix	26	Mano	132				15
118	Scilla hemisphoerica (squill)	Pistil	20			76	0.92		9
119		Stamen	20			31	0.89		9
120	S. peruviana (Cuban lily)	Pistil	20	Mano		76	0.92		1
121		Stamen	20	Mano		31	0.89		1
122		Stamen	21	Mano		37-27	0.77-0.73	Growth, development, maturation	1
123		Pistil	20	Mano		31-67	0.85-1.04	Growth, development, maturation	1
124	Sparmannia africana (African hemp)	Intact	1	Mano			0.96		3
125	Stenactis annua (fleabane)	Intact	18	Chem		40			2
126	Syringa vulgaris (lilac)	Intact	20			40			16
127	Tecoma capensis (trumpet vine)	Stamen	16	Mano		53-37-29		Growth, development, maturation	17
128	Thea sinensis (tea)	Pollen	15	Mano	690[2]		1.18		5
129	Trillium erectum (red trillium)	Anther	25	Mano	67-51			Growth, development, maturation	18
130	Tulipa gesneriana (tulip)	Intact	28				0.95		3
131		Pollen	20	Mano	300[2]				5
132	Vaccinium sp (cranberry, Howes)	Intact	24	Chem		38			19

133	Vallisneria spiralis (eelgrass)	Intact	20	Chem	30[2]				20
134	Verbascum thapsus (common mullein)	Pistil	23	Mano		82	0.92		1
135		Stamen	23	Mano		76	0.83		1
136		Sepal	23	Mano		75	0.95		1
137		Petal	23	Mano		18	0.85		1
138	Yucca gloriosa (yucca)	Pistil	16	Mano		24-23-22		Growth, development, maturation	1
139		Petal	24	Mano		67-41-44	0.91-0.97-1.07	Growth, development, maturation	1

/1/ Mano = manometric, Chem = chemical. /2/ µl/100 mg dry weight/hour.

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168. RESPIRATION RATES: HIGHER PLANTS, FRUITS

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value. For data on resting and germinating cereal-grains see HIGHER PLANTS: SEEDS, beginning on Page 348.

	Species	Condition or Part	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Aleurites sp (tung)	Intact					0.9-1.1	Growth, development, maturation	1
2		Pericarp					0.8-1.1	Growth, development, maturation	1
3	Ananus sativus (pineapple)	Intact		Chem	3		1.2		2
4	Berberis vulgaris (common barberry)	Intact	25	Mano			1.2		3
5	Bryonia dioica (bryony)	Intact	25	Chem		64-8.5		Growth, development, maturation	4
6	Capsicum frutescens (pepper, Windsor A)	Intact	24	Chem		4.0-1.4	1.12-0.88	Storage or starvation	5
7		Intact	10	Chem		1.2-0.58	1.27-0.88	Storage or starvation	5
8		Intact	0.5	Chem		0.44-0.29	0.96-0.96	Storage or starvation	5
9	Carica papaya (papaya, Solo)	Intact	4.4	Chem		0.24			6
10		Intact	7.2	Chem		0.28			6
11		Intact	10	Chem		0.46			6
12		Intact	12.8	Chem		0.62			6
13		Intact	15.6	Chem		0.83			6
14	C. papaya (papaya, Solo IV)	Intact	3.5	Chem		0.30		Storage or starvation	7
15		Intact	25	Chem		2.6-2.0-4.6		Storage or starvation	7
16	C. papaya (pawpaw)	Intact	28	Chem		5-7-6			8
17	Chelidonium majus (celandine)	Intact	28	Mano			0.99		3
18	Citrus grandis (grapefruit, Duncan)	Intact	21			1.0			9
19		Intact	10			0.4			9
20		Intact	0			0.1			9
21	C. grandis (grapefruit, Foster)	Intact	21			1.3			9
22		Intact	10			0.4			9
23		Intact	0			0.1			9

/1/ Mano = manometric, Chem = chemical.

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
24	Citrus grandis (grapefruit, Marsh)	Intact	38			2.5	2.1		9
25		Intact	21			1.0	1.1		9
26		Intact	10			0.4	1.4		9
27		Intact	0			0.1	1.2		9
28	C. grandis (grapefruit, Thompson)	Intact	21			1.3			9
29		Intact	10			0.4			9
30		Intact	0			0			9
31	C. limonia (lemon)	Intact	14.5	Chem		0.5-0.9			10
32		Intact	15	Chem		0.4-0.2	0.75-0.80	Storage or starvation	11
33		Intact	20	Chem		0.5-1.5		Hormones	12
34	C. limonia (lemon, Eureka)	Intact	38			4.1	1.4		9
35		Intact	21			1.1	1.0		9
36		Intact	10			0.5	1.1		9
37		Intact	0			0.15	1.2		9
38	C. nobilis (orange, King)	Intact	28	Mano			1.07		3
39	C. sinensis (orange, Parson Brown)	Intact	32	Chem	2.2-6.3			High frequency light; hormones	14
40		Intact	21			1.5			9
41		Intact	10			0.7			9
42		Intact	0			0.1			9
43	C. sinensis (orange, Valencia)	Intact	38				1.7		9
44		Intact	21			1.8	1.0		9
45		Intact	10			0.8	1.3		9
46		Intact	0			0.15	1.1		9
47	C. sinensis (orange, Washington Navel)	Intact	38				2.3		9
48		Intact	21			2.0	1.1		9
49		Intact	10			0.8	1.1		9
50		Intact	0			0.15	1.2		9
51	C. sinensis (sweet orange)	Intact	18			4.1	1.06		13
52	Cocos nucifera (coconut)	Endocarp and nucellus	30	Mano	400-0[2]			Growth, development, maturation	15
53	Crataegus punctata (hawthorn)	Intact	28	Mano			1.26		3
54	Cucumis sativus (cucumber, Davis Perfect)	Intact	24	Chem		2.3-0.8	1.01-0.91	Storage or starvation	5
55		Intact	10	Chem		1.0-0.4	1.01-1.10	Storage or starvation	5
56		Intact	0.5	Chem		0.2-0.08	0.97-0.88	Storage or starvation	5
57	Cytisus laburnum (broom)	Intact	28	Mano			0.87		3
58	Datura stramonium (thorn-apple)	Intact		Mano		41			16
59	Diospyros kaki (Japanese persimmon, Fuyu)	Intact	20-27			1.4	1.1		17
60	D. kaki (Japanese persimmon, Hachiya)	Intact	20-27			1.8	1.2		17
61	Fragaria sp (strawberry)	Intact	20	Chem		3.3-5.1	0.84-0.91	Growth, development, maturation	18

62	Fragaria sp (strawberry, Missionary)	Intact	5	Mano	4.2		1.2		19
63		Intact	36.5	Mano	52				19
64		Intact	40	Mano	28				19
65	F. vesca (strawberry, Alpine)	Intact	28	Mano			1.27		3
66	Hedera helix (English ivy)	Intact	20	Chem		13-50-19		Growth, development, maturation	20
67	Helianthus annuus (sunflower)	Intact	25	Mano			0.96		3
68	Hibiscus esculentus (okra)	Intact	30	Chem		306-104[2]		Storage or starvation	21
69	Hippophae rhamnoides (sea buckthorn)	Intact	20	Chem		22			16
70	Jasminum fruticans (jasmine)	Intact	18	Chem		14			16
71	Kajanus indicus (pigeon pea)	Intact	21	Chem		30-0		Growth, development, maturation	8
72	Lycopersicum esculentum (tomato)	Intact	25	Chem		28.0-4.2		Growth, development, maturation	22
73		Intact	15-18	Mano		10.0-1.2		Growth, development, maturation	23
74		Intact	27	Mano		1.7-2.9-0.7	1.07-1.01-1.23	Storage or starvation	24
75	L. esculentum (tomato, John Baer)	Intact				29.0-1.5			26
76	L. esculentum (tomato, Livingston Globe)	Intact				31.0-1.5		Growth, development, maturation	26
77	L. esculentum (tomato, Marglobe)	Intact	24	Chem		2.5-1.6	1.11-1.13	Storage or starvation	5
78		Intact	10	Chem		0.77-0.58	1.39-1.06	Storage or starvation	5
79		Intact	0.5	Chem		0.36-0.15	1.11-0.9	Storage or starvation	5
80		Intact	28	Chem		2.6-1.8	1.8-1.4	Growth, development, maturation	25
81	Malus prunifolia f. coccinea (apple)	Intact	28	Mano			1.17		3
82	Mangifera sp (green mango)	Intact	30	Chem		76-36[2]		Storage or starvation	21
83	Mangifera sp (mango, Langra)	Intact	30	Chem		15.0-2.5		Storage or starvation	27
84	Musa sapientum (banana)	Intact	15			1-3		Storage or starvation	28
85		Intact	31	Chem		3.1			29
86		Intact	20	Chem		1.8			29
87		Intact	12.5	Chem		0.9			29
88		Intact	0	Chem		0.4			29
89		Intact		Chem	6		1.02		2
90		Intact	20	Mano		6.3-8.9-6.8	1.0-1.1	Storage or starvation	30
91	M. sapientum (banana, Gros Michel)	Intact	12	Chem		0.7			31
92		Intact	16	Chem		1.2-7.6-4.4		Storage or starvation	31
93		Intact	12			3-9		Oxygen	32
94		Intact	29	Chem		2.3-14.0-4.4		Storage or starvation	33
95	Nicotiana tabacum (tobacco)	Intact	28	Mano			0.94		3
96	Papaver somniferum (opium poppy)	Intact	20	Mano	15		1.5		34
97	Persea gratissima (avocado, Fuerte)	Intact	5			1		Storage or starvation	35
98		Intact	15			2.5-8.0		Storage or starvation	35
99		Intact	25			7-15		Storage or starvation	35
100		Intact	15	Chem		5.8-3.6-8.1		Storage or starvation	36
101	P. gratissima (avocado, Nabal)	Intact	15			0.6-7.0		Oxygen; storage or starvation; hormones	35
102	Phaseolus vulgaris (snap bean)	Intact	20	Chem		4.2-7.5	0.91-0.93	Oxygen	37
103	P. vulgaris (snap bean, Tender Green)	Intact	24	Chem		16.4-6.6	1.14-1.00	Storage or starvation	5
104		Intact	10	Chem		4.6-2.0	1.08-0.98	Storage or starvation	5
105		Intact	0.5	Chem		0.95-0.65	0.94-0.96	Storage or starvation	5
106	Physalis alkekengi (winter-cherry)	Intact	28	Mano			1.4		3
107	Pimenta officinalis (red pimiento)	Intact	30	Chem		42-32[2]		Storage or starvation	21

/1/ Mano = manometric, Chem = chemical. /2/ µl/100 mg dry weight/hour.

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
108	Pisum sativum (pea) (concluded)	Intact	28	Mano			1.00		3
109	P. sativum (pea, Saxton Progress)	Intact	24	Chem		20-12	1.32-1.06	Storage or starvation	5
110		Intact	10	Chem		7.9-3.1	1.13-1.00	Storage or starvation	5
111		Intact	0.5	Chem		2.2-1.4	1.07-0.96	Storage or starvation	5
112	Polygonum scandens (climbing false buckwheat)	Intact	30				0.87		38
113		Intact	6				0.74		38
114	Prunus sp (cherry)	Intact	4	Chem		0.6			39
115	P. armeniaca (apricot, Royal)	Intact	18	Chem		2.8-4.1		Storage or starvation	39
116		Intact	4	Chem		1.1-1.0		Storage or starvation	39
117	P. avium (sweet cherry)	Intact	28	Mano			1.70		3
118		Intact	20	Chem		68-2		Growth, development, maturation	40
119	P. domestica (plum)	Intact	18	Chem		8.7			16
120		Intact	28	Mano			2.5-4.4		3
121	P. domestica (plum, Santa Rosa)	Intact	18	Chem		1.7-3.6		Storage or starvation	39
122		Intact	4	Chem		0.5			39
123	P. persica (peach, Peregrine)	Intact	25	Chem		7-5		Growth, development, maturation	41
124		Intact	25	Chem		8-2		Storage or starvation	41
125	P. persica (peach, Primrose)	Intact	18	Chem		1.4-2.0		Storage or starvation	39
126		Intact	4	Chem		0.4-0.3		Storage or starvation	39
127	P. salicina (plum, Japanese)	Intact	18			13.7	1.3		13
128	P. salicina (plum, Kelsey)	Intact	25	Chem		4.0-1.8		Growth, development, maturation	41
129		Intact	25	Chem		4.0-0.9		Storage or starvation	41
130	P. spinosa (sloe)	Intact	28	Mano			1.5		3
131	Psidium sp (guava)	Intact	30	Chem		20.0-3.6		Storage or starvation	27
132	Pyrus communis (pear)	Intact	10	Chem		0.5-3.5		Storage or starvation	42
133	P. communis (pear, Anjou)	Intact	18	Chem		0.3-0.7		Hormones	43
134	P. communis (pear, Bartlett)	Intact				0.7-5.6		Storage or starvation; hormones	44
135		Intact	18	Chem		6.3-1.0-1.2		Growth, development, maturation	45
136		Intact	18	Chem		1.0-0.8-2.2		Storage or starvation	45
137	P. malus (apple)	Intact	18			1	1.09		13
138	P. malus (apple, Bramley's Seedling)	Intact	22	Chem		2.0-3.5		Storage or starvation	46
139		Intact	12	Chem		11-0.25		Growth, development, maturation	47
140		Intact	18	Chem		16-0.6			47
141		Intact	22.5	Chem		1.1-1.6-0.6		Storage or starvation	48
142		Intact	10	Chem		0.4-0.5-0.3		Storage or starvation	48
143		Intact	2.5	Chem		0.2-0.3-0.2		Storage or starvation	48
144		Intact	12	Chem		1.9-0.9		Storage or starvation	49
145		Intact	12	Chem		0.8-0.4-0.8		Storage or starvation	49
146		Intact	12	Chem		1.9-0.8		Growth, development, maturation	49
147	P. malus (apple, Delicious)	Intact	20	Chem		1.7-0.4-0.4		Growth, development, maturation	52
148	P. malus (apple, Golden Delicious)	Intact	20	Chem		1.8-0.5-1.3		Growth, development, maturation	52

149	P. malus (apple, Grimes Golden)	Intact	-1	Chem		0.18			50
150	P. malus (apple, Jonathan)	Intact	27	Mano		2.4-5.1-0.6	0.43-0.91	Growth, development, maturation	51
151		Intact	20	Chem		1.7-0.8-0.8		Growth, development, maturation	52
152	P. malus (apple, Maiden Blush)	Intact	25	Chem		4.2-20.0		Storage or starvation	54
153		Intact	0	Chem		1.4-2.4		Storage or starvation	54
154	P. malus (apple, McIntosh)	Intact	22	Chem		25-1		Storage or starvation; growth, development, maturation	53
155	P. malus (apple, Oldenburg)	Intact	25	Chem		2.6-1.6		Storage or starvation	54
156		Intact	0	Chem		9.2-1.6		Storage or starvation	54
157	P. malus (apple, Winesap)	Intact	25	Chem		1.9-0.9		Storage or starvation	54
158		Intact	0	Chem		1.8-0.6		Storage or starvation	54
159	P. malus (apple, Yellow Newtown)	Intact	20	Chem		1.4-0.4-0.9		Growth, development, maturation	52
160	Quercus alba (white oak)	Intact	2.5	Mano	17[2]		0.16		55
161		Intact	10	Mano	16[2]		0.30		55
162		Intact	20	Mano	18[2]		0.47		55
163		Intact	30	Mano	21[2]		0.71		55
164	Q. borealis var. maxima (Northern red oak)	Intact	2.5	Mano	20[2]		0.08		55
165		Intact	10	Mano	23[2]		0.13		55
166		Intact	20	Mano	11[2]		0.29		55
167		Intact	30	Mano	14[2]		0.46		55
168	Ribes grossularia (European gooseberry)	Intact	28	Mano			1.6		3
169	R. rubrum (Northern red currant)	Intact	28	Mano			1.4		3
170	Ricinus communis (castor bean)	Intact	28	Mano			1.07		3
171	Rosa sp (rose)	Intact	28	Mano			0.86		3
172	Sambucus nigra (European elder)	Intact	25	Mano			1.20		3
173		Intact	18	Chem		12			16
174	Secale cereale (rye, Abbruzzi)	Intact	28	Mano	245-12[2]			Growth, development, maturation	56
175	Solanum lycopersicum (nightshade)	Intact	28	Mano			1.9		3
176	Sorbopirus auricularis	Intact	28	Mano			0.94		3
177	Sorbus hybrida (chokeberry)	Intact	22	Mano	3.6-2.5		0.93-0.84-1.06	Growth, development, maturation	57
178	S. scandica (chokeberry)	Intact	32	Mano	6.3-1.3		1.0-1.4-0.8-1.5	Growth, development, maturation	57
179	Symphoricarpus racemosa (snowberry)	Intact	25	Mano			0.97		3
180		Intact	17	Chem		33			16
181	Syringa vulgaris (lilac)	Intact	25	Chem		42.0-8.5		Growth, development, maturation	22
182	Triticum vulgare (wheat, Leapland)	Intact	28	Mano	340-8[2]			Growth, development, maturation	56
183	Vaccinium sp (cranberry, Howes)	Intact	24	Chem		32-14		Growth, development, maturation	58
184	V. myrtillus (whortleberry)	Intact	28	Mano			1.25		3
185	Vitis sp (grape, Thompson Seedless)	Intact	18	Chem		0.9			39
186	V. vinifera (wine grape)	Intact	28	Mano			1.6		3
187	Zea mais (corn, Hopeland Sweet)	Intact	30	Chem		21-13		Growth, development, maturation	25
188	Z. mais (corn, Stowell's Evergreen Sweet)	Intact	28	Chem		17-11			25
189		Intact	4.5	Chem		3.5			25

/1/ Mano = manometric, Chem = chemical. /2/ µl/100 mg dry weight/hour.

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169. RESPIRATION RATES: HIGHER PLANTS, WHOLE ORGANISMS

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, unless otherwise specified. Underlined number = control or endogenous value.

	Species	Condition or Part	Temp °C	Method[1]	Respiration Rate µl/100 mg/hr Q_{O_2}	Respiration Rate µl/100 mg/hr Q_{CO_2}	R.Q. CO_2/O_2	Experimental Variable	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Betula nana (birch)	Intact	16	Mano		7.0[2]	0.93		1
2	Brassica oleracea (cabbage)	Intact	2	Chem		34.0-8.5[3]		Storage or starvation	2
3	Echinocereus fendleri (spiney cereus)	Intact	25			2-1			3
4	Ferocactus wislizeni (wild cactus)	Intact	25			1.4-0.5		Storage or starvation	3
5	Gossypium herbaceum (cotton, Roseum)	Intact	38	Chem		198-65[3]		Growth, development, maturation	4
6	Helianthus annuus (sunflower, Sutton's Giant Yellow)	Intact	10	Chem		148-13[3]		Growth, development, maturation	5
7	Impatiens sp (balsam)	Intact	38	Chem		390-91[3]		Growth, development, maturation	4
8	Ipomoea batatas (sweet potato, Big Stem Jersey)	Intact	21	Mano		1-2		Wounding	6
9	Mamillaria newmanniana (cactus)	Intact	23 & 31	Mano		2.7-2.5	0.79-0.00	Light or photoperiod	7
10		Intact	31	Mano		2.7			7

11		Intact	10	Mano		1.0			7
12	Neomammillarea microcarpa (haw)	Intact	25			1.2-0.8		Storage or starvation	3
13	Nicotiana tabacum (tobacco, Samsun)	Intact		Chem		7.7-10.0		Healthy vs diseased	8
14	Opuntia engelmannii (prickly pear)	Intact	25			1.0-1.5		Storage or starvation	3
15	O. versicolor (prickly pear)	Intact	25			3		Storage or starvation	3
16	Pelargonium zonale (horseshoe geranium)	Intact	13				0.54		9
17	Pistea sp (water lettuce)	Shoot	35	Chem		204-85[3]		Storage or starvation	14
18	Ricinus communis (castor bean)	Intact	30	Mano	180		0.78		10
19	Sedum hybridum (stonecrop)	Intact	26				0.37		9
20	Solanum tuberosum (potato, Arran Comrade)	Intact	19	Chem		10.7-14.3		Healthy vs diseased	11
21	Trianea sp (false asphodel)	Intact	17	Chem		29			12
22	Triticum vulgare (wheat, Minhardi)	Intact	2	Chem		38-13[3]		Storage or starvation	2
23	Veronica anagallis (speedwell)	Intact	18			31-17		Growth, development, maturation	13

/1/ Mano = manometric, Chem = chemical. /2/ µl/sq cm/hour. /3/ µl/100 mg dry weight/hour.

Contributors: (a) Mandels, G. R., and Darby, R. T., (b) Klein, R. M., (c) Henderson, J. H., and Henderson, L. L., (d) Chapman, H. W., (e) Vallance, K. B.

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APPENDIXES

APPENDIX I. CONSTANTS FOR USE IN BODY SURFACE AREA FORMULA: MAMMALS

K-values are derived from surface area values taken from extensive literature sources, using the formula $K = A(\text{sq cm})W^{2/3}(\text{g})$. Weights are given in grams for convenient use in the formula and do not imply significance corresponding to number of digits. Method of determining surface area: C = paper cover, I = surface integrator, M = mold, P = perimeter, S = skinning, T = triangulation. Values in parentheses are ranges, estimates "c" (body weight) and "d" (K-value) of the 95% range (cf Introduction).

	Animal	Subjects, no.	Method	Body Weight, g	K-value (Constant)	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Antelope	1	T	6300	14.1	1
2	Bat	3	S	21.5(12.7-36.4)	57.5(54.0-59.8)	2
3	Bat	2	S	8.3(5.0-11.6)	44.5(44.0-45.0)	3
4	Cat	2	T	1550(1500-1600)	8.7(8.6-8.9)	1
5	Cat[1]	2	S	100(84-116)	10.0(9.9-10.0)	4
6	Cat[1]	3	S	708(219-1389)	10.7(9.5-11.9)	4
7	Cattle, Hereford-Shorthorn[1]	15	S	375,000(163,000-641,000)	11.0(9.0-13.8)	5
8	Cattle, Hereford-Shorthorn	15	S	476,000(208,000-762,000)	9.3(8.1-10.8)	5
9	Cattle, Hereford-Shorthorn (thin)[1]	10	S	241,000(89,000-407,000)	9.9(9.3-10.5)	6
10	Cattle, Hereford-Shorthorn (med.)[1]	11	S	315,000(78,000-493,000)	9.4(8.8-10.0)	6
11	Cattle, Hereford-Shorthorn (fat)[1]	7	S	695,000(476,000-815,000)	7.6(7.3-7.9)	6
12	Dog	6	S	1070(130-3650)	10.1(9.3-11.0)	4
13	Dog	1	S	1080	11.0	7
14	Dog	2	T	9,500(8,900-10,100)	9.9(9.85-9.9)	1
15	Dog	8	S and P	12,700(3,200-29,800)	11.6(10.2-12.5)	8
16	Dog	7	M	14,310(3,390-32,640)	11.2(10.3-12.1)	9
17	Dog	1	C	27,000	12.3	10
18	Fox	2	T	6200(6100-6300)	13.0(12.9-13.2)	1
19	Goat	1	T	15,100	10.5	1
20	Guinea pig	3	S	157(123-191)	10.4(10.1-10.8)	11
21	Guinea pig	6	S	206(123-269)	9.5(8.4-10.8)	11
22	Guinea pig	3	S	256(235-269)	8.6(8.4-8.9)	11
23	Guinea pig[2]	13	S	323(160-810)	8.9(7.9-9.6)	12
24	Guinea pig	3	S	373(148-650)	9.6(9.0-9.9)	13
25	Guinea pig	2	T	400(380-420)	7.1	1
26	Hedgehog	1	S	200	7.5	7
27	Horse	8	S	(47,000-555,000)	10.5	14
28	Horse	11	I	(70,000-750,000)	(8.2-10.3)	15
29	Lion	1	T	64,200	12.3	1
30	Marten, pine	1	T	1400	8.8	1
31	Monkey, rhesus	6	M	2670(800-6600)	11.8(10.8-13.2)	16
32	Mouse, white[2]	64	S	13	6.9	11, 17
33	Mouse, white	11	S	15(6-27)	7.9	18
34	Mouse, white	3	S	16(11-20)	10.5(10.4-10.5)	13
35	Mouse, white	12	S	16(10-22)	11.4(9.7-13.3)	11
36	Mouse, white	13	M	(16-25)	9.0(8.4-9.4)	19
37	Mouse, field	2	S	29(26-31)	6.9(6.5-7.2)	3
38	Opossum	4	S	1200(1000-1300)	11.3(10.5-11.8)	20
39	Rabbit[3]	3	S	32(26-40)	8.5	18
40	Rabbit[3]	3	S	560(70-925)	9.7	18
41	Rabbit	2	T	1130(1120-1140)	10.0(9.0-11.0)	1
42	Rat, white	5	S	42(35-53)	10.5(10.1-10.8)	16
43	Rat, white	5	S	80(50-129)	9.9(9.6-10.4)	21
44	Rat, white[2]	14	M	95(22-164)	7.6(7.3-8.8)	22
45	Rat, white	56	M	125(24-366)	7.5(6.6-8.3)	22
46	Rat, white	14	S	133(70-310)	11.6(10.9-12.1)	16
47	Rat, white	2	T	170(164-177)	7.15	1
48	Rat, white	62	S	176(25-461)	11.4(9.6-13.0)	23
49	Rat, white	72	M	(19-418)	9.0	24
50	Rat, white	22	S	197(65-335)	10.5(9.0-12.7)	25
51	Sheep	8	S	(21,800-29,100)	10.7	26
52	Sheep	115	I	(2,200-68,000)	8.3	27
53	Sheep	14	S	(23,600-37,700)	8.5	28
54	Sheep	15	S	(3,780-50,400)	9.1	26
55	Shrew, long-tailed	1	S	3.5	8.0	3
56	Shrew, short-tailed	1	S	20	7.0	3
57	Swine	1	T	40,110	15.3	1
58	Swine	16	I	(25,000-330,000)	9.0	15
59	Swine	7	S	48,300(1,100-123,000)	9.9(8.6-12.4)	5
60	Whale, fin	3	P	160,000(115,000-220,000)	8.3(7.5-8.9)	29
61	Whale, fin	1	P	43,000,000	11.1	29
62	Woodchuck	1	M	1236	9.3	16

/1/ "Empty" weight. /2/ Starved animals. /3/ With surface area of one side of ear only.

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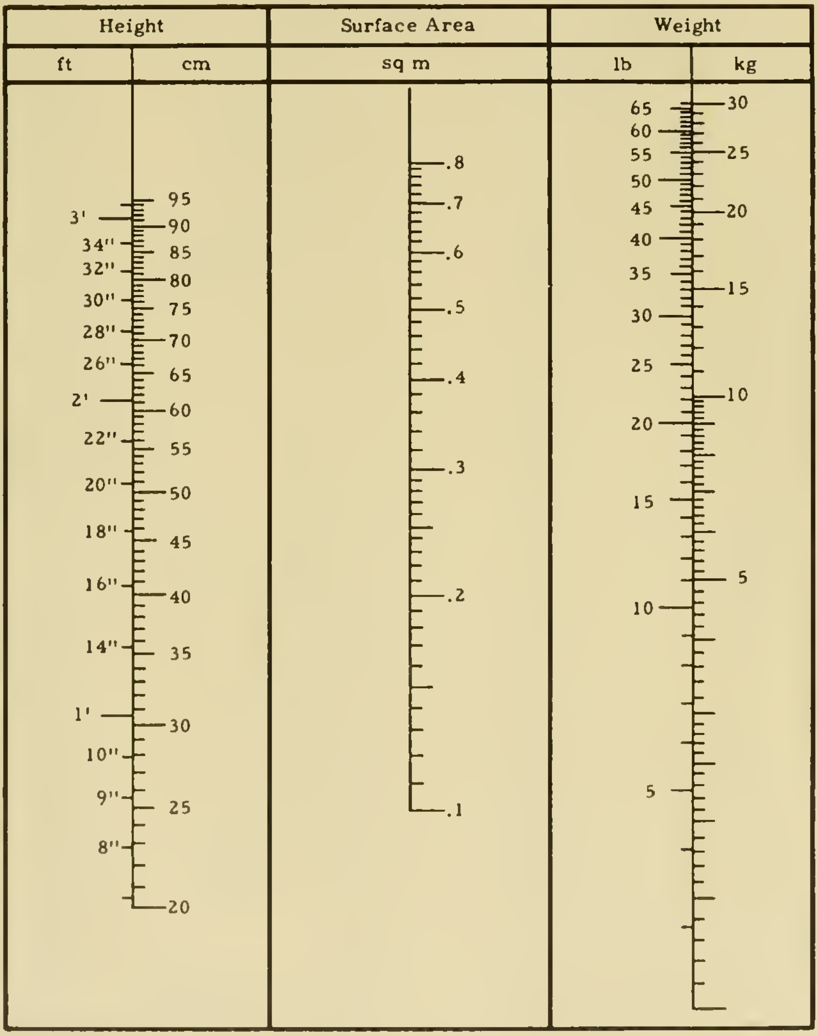
APPENDIX II. BODY SURFACE AREA: INFANTS AND YOUNG CHILDREN

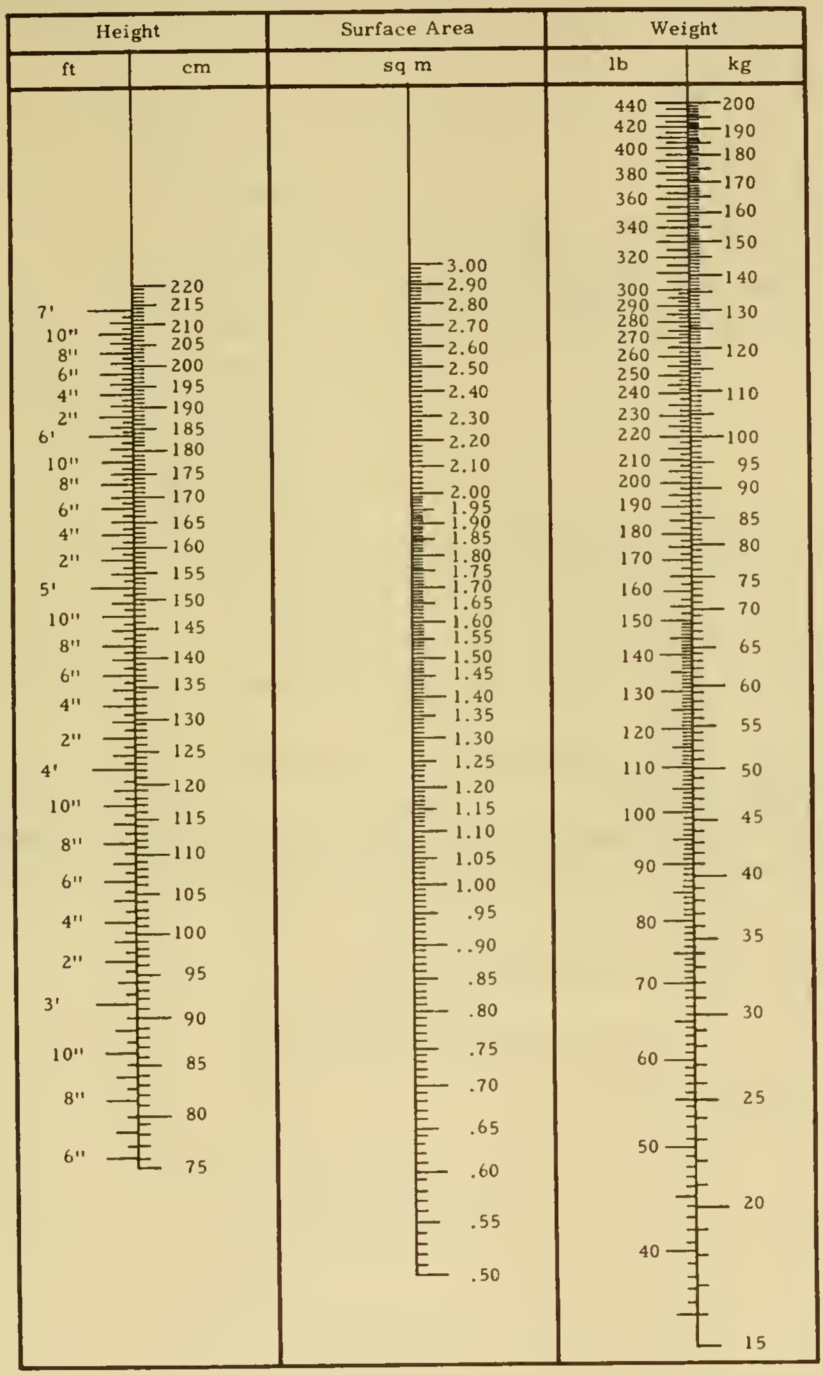
Nomogram is based on formula appearing in DuBois, D., and DuBois, E. F., Proc. Soc. Exp. Biol. 13:77, 1916.



Reference: Talbot, N. B., Sobel, E. H., McArthur, J. W., and Crawford, J. D., "Functional Endocrinology from Birth through Adolescence," Cambridge, Mass.: The Commonwealth Fund, Harvard University Press, 1952 (as quoted in "Fluid and Electrolytes," Abbott Laboratories, North Chicago, Ill.).

APPENDIX III. BODY SURFACE AREA: OLDER CHILDREN AND ADULTS

Nomogram is based on formula appearing in DuBois, D., and DuBois, E. F., Proc. Soc. Exp. Biol. 13:77, 1916.



Reference: Talbot, N. B., Sobel, E. H., McArthur, J. W., and Crawford, J. D., "Functional Endocrinology from Birth through Adolescence," Cambridge, Mass.: The Commonwealth Fund, Harvard University Press, 1952 (as quoted in "Fluid and Electrolytes," Abbott Laboratories, North Chicago, Ill.).

APPENDIX IV. STANDARD SYMBOLS IN RESPIRATORY PHYSIOLOGY

The following symbols conform to standards adopted by pulmonary physiologists, as published in Federation Proceedings 9:602, 1950. Use of these symbols throughout the HANDBOOK OF RESPIRATION was not feasible because of mechanical limitations in the preparation of copy.

Primary Symbols
(Large capital letters)

V = gas volume

$\dot{V}$ = gas volume/unit time

P = gas pressure in mm Hg

F = fractional concentration in dry gas phase

f = respiratory frequency, breaths/unit time

R = respiratory exchange ratio, $\dot{V}_{CO_2}/\dot{V}_{O_2}$

Secondary Symbols
(Small capital letters)

I = inspired gas

E = expired gas

A = alveolar gas

T = tidal gas

D = dead space gas

B = barometric

STPD = standard temperature and pressure, dry ($0^{\circ}C$, 760 mm Hg)

BTPS = body temperature and pressure, saturated with water vapor

ATPD, ATPS = ambient temperature and pressure, dry or saturated

V_A (alveolar ventilation) is in L/min (BTPS). $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ are in ml/min (STPD). Dash (–) above any symbol indicates a mean value. Dot (˙) above any symbol indicates a time derivative.

The following conventions for symbols denote location and molecular species:

1. Localization in the gas phase is represented by a small capital letter immediately following the principal variable.

2. Molecular species is denoted by the full chemical symbol, printed in small capital letters immediately following the principal variable.

3. When specification of both location and molecular species is required, the first modifying letter is used for localization and the second for species. In the latter case, the chemical symbol appears as a subscript.

Contributor: Swann, H. G.

Reference: Comroe, J. H., Jr., et al, Fed. Proc. 9:602, 1950.

APPENDIX V. RESPIRATORY EQUATIONS

I. O_2 consumption and CO_2 production:

$$(1)\quad \dot{V}_{O_2} = \dot{V}_E \frac{[F_{I_{O_2}}(1-F_{E_{CO_2}}) - F_{E_{O_2}}(1-F_{I_{CO_2}})]}{(1-F_{I_{O_2}} - F_{I_{CO_2}})}. \qquad [1]$$

$$(2)\quad \dot{V}_{CO_2} = \dot{V}_E \frac{[F_{E_{CO_2}}(1-F_{I_{O_2}}) - F_{I_{CO_2}}(1-F_{E_{O_2}})]}{(1-F_{I_{O_2}} - F_{I_{CO_2}})}. \qquad [1]$$

II. Alveolar gas equations:

If $V_{I_{CO_2}} = 0$,

$$(3)\quad P_{A_{O_2}} = F_{I_{O_2}}(P_B - P_{A_{H_2O}}) - P_{A_{CO_2}}\left[F_{I_{O_2}} + \frac{(1 - F_{I_{O_2}})}{R_A}\right]. \qquad [1]$$

$$(4)\quad P_{A_{O_2}} = P_{I_{O_2}} - \frac{.863\,\dot{V}_{O_2}(1 - F_{I_{O_2}})}{\dot{V}_A} - F_{I_{O_2}} \times P_{A_{CO_2}}. \qquad [2]$$

If $V_{I_{CO_2}} > 0$,

$$(5)\quad P_{A_{O_2}} = \frac{P_{I_{O_2}}R + P_{A_{CO_2}}F_{I_{O_2}}(1 - R) + P_{I_{CO_2}} - P_{A_{CO_2}}}{F_{I_{CO_2}}(1 - R) + R}. \qquad [2]$$

III. Alveolar ventilation equations ($V_{I_{CO_2}} = 0$):

$$(6)\quad \dot{V}_A = (V_T - V_D)f. \qquad [1]$$

$$(7)\quad \dot{V}_A = \frac{\dot{V}_{CO_2}}{F_{A_{CO_2}}}. \qquad [1]$$

$$(8)\quad \dot{V}_A = \frac{R_A}{F_{A_{CO_2}}} \cdot \dot{V}_{O_2}. \qquad [1]$$

$$(9)\quad \dot{V}_A = (P_B - P_{A_{H_2O}}) \cdot \frac{R_A}{P_{A_{CO_2}}} \cdot \dot{V}_{O_2}. \qquad [1]$$

In equations (6)-(9), $\dot{V}_A$ and $\dot{V}_{CO_2}$ are under the same conditions and in the same units. However, the general condition for $\dot{V}_{CO_2}$ is at STPD and for $\dot{V}_A$ at BTPS. If, furthermore, we express the former in ml/min and the latter in L/min and change $F_{A_{CO_2}}$ to $P_{A_{CO_2}}$, we have customary units for all parameters at any barometric pressure. After these changes, equation (7) becomes

$$(10)\quad \dot{V}_A\,(\text{L/min, BTPS}) = \frac{\dot{V}_{CO_2}(\text{ml/min, STPD}) \times .863}{P_{A_{CO_2}}}, \text{ and} \qquad [2]$$

$$(11)\quad \dot{V}_A = \frac{\dot{V}_{O_2} \times R \times .863}{P_{A_{CO_2}}}. \qquad [2]$$

IV. Respiratory dead space equations:

$$(12)\quad V_A = (V_T - \frac{\dot{V}_A}{f}). \qquad [1]$$

Bohr Equation using any gas x (at BTPS):

$$(13)\quad V_{D_x} = \frac{(F_{E_x} - F_{A_x})}{(F_{I_x} - F_{A_x})} \cdot V_T. \qquad [1]$$

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References: [1] Comroe, J. H., Jr., et al, Fed. Proc. 9:602, 1950. [2] Rahn, H., and Fenn, W. O., "A Graphical Analysis of the Respiratory Gas Exchange: The O_2 - CO_2 Diagram," Washington, D. C.: The American Physiological Society, 1955.

APPENDIX VI. SUMMARY: VALUES USEFUL IN PULMONARY PHYSIOLOGY

Values for a healthy, resting, recumbent young man (1.7 sq m surface area) breathing air, unless other conditions are specified. These values may change with position, age, size, sex and altitude; there is variability among members of a homogenous group under standard conditions.

	Variable	Value
	Lung Volumes (BTPS)	
1	Inspiratory capacity	3600 ml
2	Expiratory reserve volume	1200 ml
3	Vital capacity	4800 ml
4	Residual volume	1200 ml
5	Functional residual capacity	2400 ml
6	Total lung capacity	6000 ml
7	Residual volume/total lung capacity x 100	20%
	Ventilation (BTPS)	
8	Tidal volume	500 ml
9	Frequency	12 respirations/min
10	Minute volume	6000 ml/min
11	Respiratory dead space	150 ml
12	Alveolar ventilation	4200 ml/min
	Distribution of Inspired Gas	
13	Single-breath test (% increase N_2 for 500 ml expired alveolar gas)	<1.5% N_2
14	Pulmonary nitrogen emptying rate (7 min test)	<2.5% N_2
15	Helium closed circuit (mixing efficiency related to perfect mixing)	76%
	Alveolar Ventilation/Pulmonary Capillary Blood Flow	
16	Alveolar ventilation (L/min)/blood flow (L/min)	0.8
17	Physiological shunt/cardiac output x 100	<7%
18	Physiological dead space/tidal volume x 100	<30%
	Pulmonary Circulation	
19	Pulmonary artery pressure	25/8 mm Hg
20	Pulmonary capillary blood pressure	8 mm Hg
21	Pulmonary capillary blood flow	5400 ml/min
22	Pulmonary capillary blood volume	60-100 ml
	Alveolar Gas	
23	O_2 partial pressure	104 mm Hg
24	CO_2 partial pressure	40 mm Hg

	Variable	Value
	Diffusion and Gas Exchange	
25	O_2 consumption (STPD)	250 ml/min
26	CO_2 output (STPD)	200 ml/min
27	Respiratory exchange ratio, (CO_2 output/O_2 uptake)	0.8
28	Diffusing capacity, O_2 (STPD)	20 ml O_2/min/mm Hg
29	Diffusing capacity, CO (steady state) (STPD)	17 ml CO/min/mm Hg
30	Diffusing capacity, CO (single breath) (STPD)	17 ml CO/min/mm Hg
31	Fractional CO uptake	53%
32	Maximal diffusing capacity (exercise) (STPD)	60 ml/min/mm Hg
	Arterial Blood	
33	O_2 saturation (% saturation of Hb with O_2)	97.1%
34	O_2 tension	95 mm Hg
35	CO_2 tension	40 mm Hg
36	Alveolar-arterial pO_2 difference	9 mm Hg
37	Alveolar-arterial pO_2 difference (12-14% O_2)	10 mm Hg
38	Alveolar-arterial pO_2 difference (100% O_2)	35 mm Hg
39	O_2 saturation (100% O_2)	100% (+1.91-2.00 ml dissolved O_2/100 ml blood)
40	pH	7.40
	Mechanics of Breathing	
41	Maximal breathing capacity (BTPS)	125-170 L/min
42	Timed vital capacity (% of total vital capacity)	83% in 1 sec, 97% in 3 sec
43	Maximal expiratory flow rate (for 1 L) (ATPS)	400 L/min
44	Maximal inspiratory flow rate (for 1 L) (ATPS)	300 L/min
45	Compliance of lungs and thorax	0.1 L/cm H_2O
46	Compliance of lungs	0.2 L/cm H_2O
47	Airway resistance	1.6 cm H_2O/L/sec
48	Work of quiet breathing	0.5 kg-m/min
49	Maximal work of breathing	10 kg-m/breath
50	Maximal inspiratory and expiratory pressures	60-100 mm Hg

Reference: Comroe, J. H., Jr., et al, p 171, "The Lung," Chicago: The Year Book Publishers, 1956.

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Asterisk (*) indicates graph or diagram.